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REQUIREMENTS FOR AVIONICS FOR VTOL TERMINAL AREA NAVIGATION, GUIDANCE AND CONTROL (V/STOLAND)

(NASA-TM-X-70201) REQUIREMENTS FOR AVIONICS FOR VTOL TERMINAL AREA NAVIGATION, GUIDANCE AND CONTROL (V/STOLAND) (NASA) ~~81~~ 80 p

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1.0 SCOPE

This specification sets forth the requirements for the analysis, design, development, fabrication, test, integration, installation, checkout and maintenance of airborne electronics (avionics) equipment with its computer programs that will provide a terminal area navigation, guidance and control function for a V/STOLAND research aircraft. The avionics hardware and software are referred to herein as V/STOLAND. This specification also covers ground support equipment and special checkout equipment for V/STOLAND. V/STOLAND will interface with government-furnished ground navigation aids, pilot, data acquisition equipment, and aircraft, to provide a complete V/STOLAND terminal area navigation, guidance and control research system.

2.0 APPLICABLE DOCUMENTS

The following documents of the issue in effect on date of contract form a part of this specification to the extent specified herein. In the event of conflict between this specification and other documentation referenced herein, the requirements of this specification shall prevail.

Military

MIL-STD-882	Safety Engineering of Systems and Associated Subsystems and Equipment: General Requirements for
MIL-STD-810B	Environmental test Methods for Aerospace and Ground Equipment as applicable in Section 4 of Spec
MIL-STD-461A	Electromagnetic Interference Characteristics, Requirements for Equipment
MIL-B-5087B Amendment	Bonding, Electrical and Lightning Protection for Aerospace Systems
AFSC DH 1-4	Electromagnetic Compatibility Handbook
MIL-STD-704A	Electric Power, Aircraft, Characteristics and Utilization of
MIL-Hndbk-5B	Military Standardization Handbook - Metallic Materials and Aerospace Vehicle Structures
FAA Regulations Vol IV, Part 29	Airworthiness Standards; Transport Category Rotorcraft (Part 29)
MIL-Hndbk-694A	Aluminum and Aluminum Alloys Handbook

NASA

AHB 5328-1	Preferred Parts and Materials List (Ames Research Center)

NHB 5300.4(1A)	Reliability Program Provisions for Aeronautical and Space Systems Contractors
NHB 5300.4(1B)	Quality Program Provisions for Aeronautical and Space Systems Contractors

FAA Advisory Circular AC No. 29.1 - Approval Basis for Automatic Stabilization Equipment Installations on Rotorcraft. (Paragraphs 4.a and 4.b of this document are excluded.)

2.1 Guidelines Documents

The following documents shall be used as a guide in the construction of equipment, in the modifications to the aircraft, and in the installation practices required to install and operate such equipment on board the aircraft. If conflicting requirements exist the lowest numbered document shall take precedence.

1. FAA Advisory Circular AC No. 29.773-1
   Pilot Compartment View

2. FAA Advisory Circular AC No. 43.13-1A
   Acceptable Methods, Techniques and Practices - Aircraft Inspection and repair

3. FAA Advisory Circular AC No. 43.13-2
   Acceptable Methods, Techniques and Practices - Aircraft Alterations

4. FAA Advisory Circular AC No. 65-9
   Airframe and Power Plant Mechanics General Handbook

5. FAA Advisory Circular AC No. 65-12
   Airframe and Powerplant Mechanics Airframe Handbook

6. Air Force Systems Command (AFSC) Design Handbooks
   Series 1-0, 2-0, and 4-0

7. MIL-STD-250C — Aircrew Station Controls and Displays for Rotary Winged Aircraft

8. MIL-Hndbk-5B — Military Standardization Handbook - Metallic Materials and Aerospace Vehicle Structures

9. MIL-Hndbk-694A — Aluminum and Aluminum Alloys Handbook

10. MIL-F-9490C — Flight Control Systems Design Installation and Test of Piloted Aircraft - General Requirements for

11. MIL-E-7080B — Electronic, Equipment, Aircraft, Selection and Installation of

12. MIL-E-5400N — Electronic Equipment, Airborne, General Specification

13. MIL-E-25499C — Electrical Systems, A/C design and Installation of, General requirements for

14. MIL-STD-882 — Safety Engineering of Systems and Associated Subsystems and Equipment, General requirements for

15. MIL-STD-810B — Environmental Test Methods for Aerospace and Ground Equipment

16. SP 6502 — Elements of Design Review for Space Systems

17. FAA Advisory Circular AC No. B5-15 — Airframe and Power Plant Mechanics Airframe Handbook

3.0 REQUIREMENTS

3.1 Objective

The objective of the V/STOLAND Flight Research Program is to develop operational and design criteria for V/STOLAND operational and design transport operations utilizing advanced VTOL vehicles such as the tilt-rotor aircraft. The objective of V/STOLAND is to develop an airborne hardware/software system to provide the navigation, guidance, control, and displays for that portion of the NASA/ARC V/STOLAND Flight Research Program to be conducted with the UH-1B helicopter. V/STOLAND hardware and software shall be as identified herein.

The V/STOLAND described by this specification will be used for terminal area operation, approach, and landing research on a NASA/ARC UH-1 helicopter. Flight equipment shall be developed to allow evaluation of the aircraft's V/STOLAND performance as a function of avionics automation level, flight path geometry, operational environment and ground navigation aids. This specification requires V/STOLAND to operate through approach and landing touchdown in discrete configurations which represent selected degrees of automation from fully automatic to manual only. V/STOLAND shall utilize microwave scanning beam landing guidance system (MODILS) and Multilateration ranging system (MRS) as landing aid candidates. V/STOLAND shall also use TACAN and VOR/DME to allow terminal area navigation and landing approach research.

3.2 Program Approach

Uncertainties exist in the dynamic response characteristics of the experimental aircraft and its control system. Therefore, the V/STOLAND shall provide adjustable control feedback gains to compensate for the aircraft uncertainties.

The NASA/ARC simulation will be an important feature of the program, and this specification requires V/STOLAND to interface with the simulation to allow demonstration of full V/STOLAND capabilities for the UH-1 helicopter. The NASA/ARC simulation is defined in Section 3.9.6.2.

One shipset of avionics hardware will be used alternately in the research vehicle and the NASA/ARC simulation. To facilitate equipment transfer two sets of cables, actuators, and control sensors will be used, one set each for the research vehicle and the simulation facility. Installation of the flight avionics in the simulation shall be possible by installing individual units into the simulation equipment rack, or by removing the flight equipment rack from the aircraft and interfacing it with the simulation. Equipment transfer should require no more than two eight-hour shifts; successful completion of transfer shall be verified by operation of the system preflight test.

In order to meet accuracy and safety requirements and to maximize applicability to the time period of interest, the avionics must be constructed using the most promising technology and techniques that can be reliably constructed and installed. An important consideration is that the V/STOLAND minimize the pilot's workload and enhance his ability to operate the aircraft safely in the terminal area when flying on instruments. All design requirements must be implemented with full consideration for safety in the flight research program.

3.3 V/STOLAND Flight Research System

The elements of V/STOLAND are diagrammed in Figure 3.3(a). The arrangement for interfacing V/STOLAND with the NASA/ARC simulation is shown in Figure 3.3(b).

3.3.1 Description of V/STOLAND Elements

V/STOLAND shall consist of the elements described herein. System design requirements are given in Section 3.6.1.

3.3.1.1 Air Data Sensors

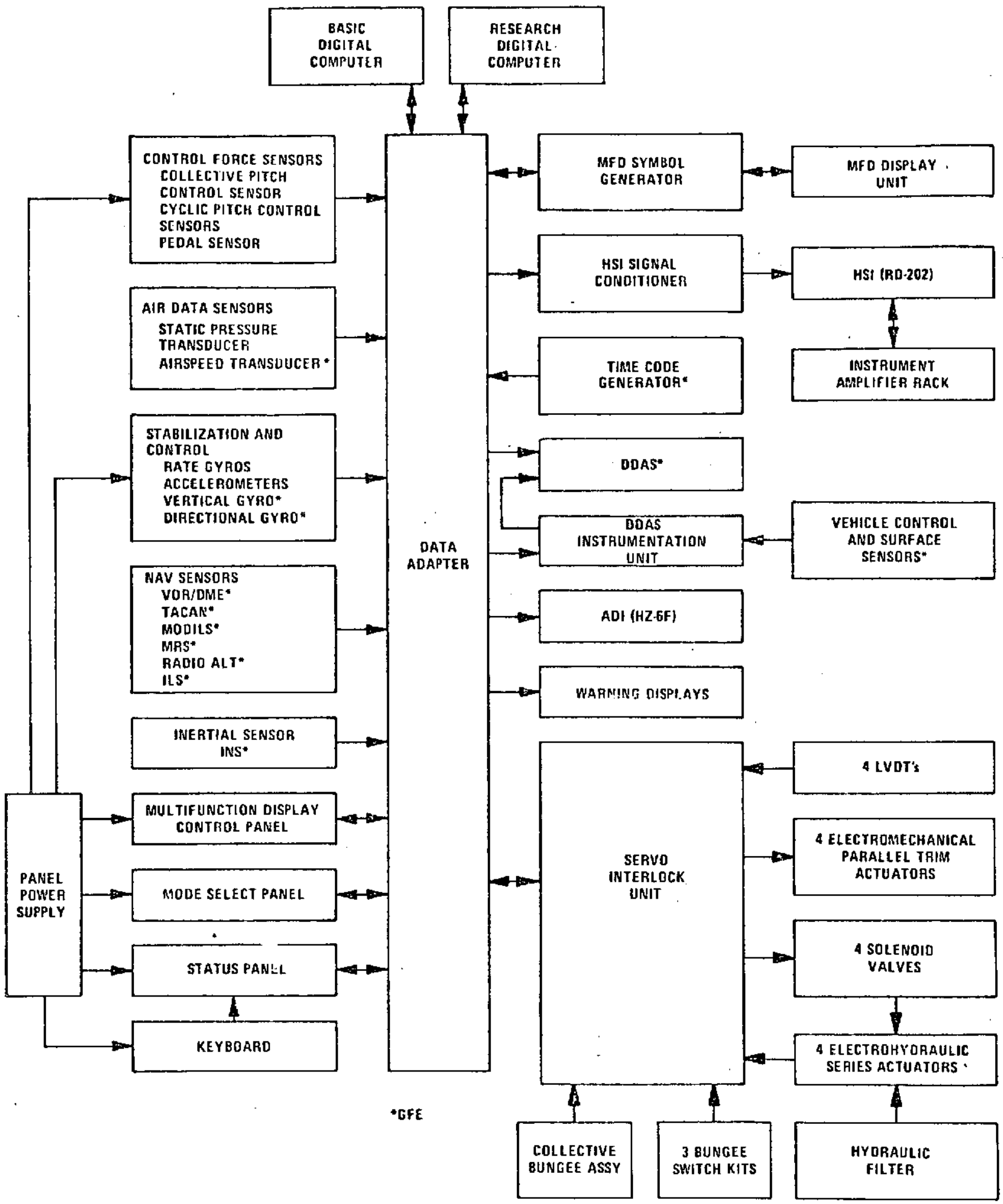
V/STOLAND shall include a static pressure transducer which shall interface with GFE static pressure port and a GFE airspeed transducer. For the UH-1 helicopter, V/STOLAND shall not include a total temperature sensor. Data for temperature correction of the static pressure transducer shall be provided by a sensor integral to that transducer. The interfaces shall be depicted and controlled in the Aircraft Interface Document, Section 3.9.5. Detailed requirements are given in Section 3.6.2.

3.3.1.2 Stabilization and Control Sensors

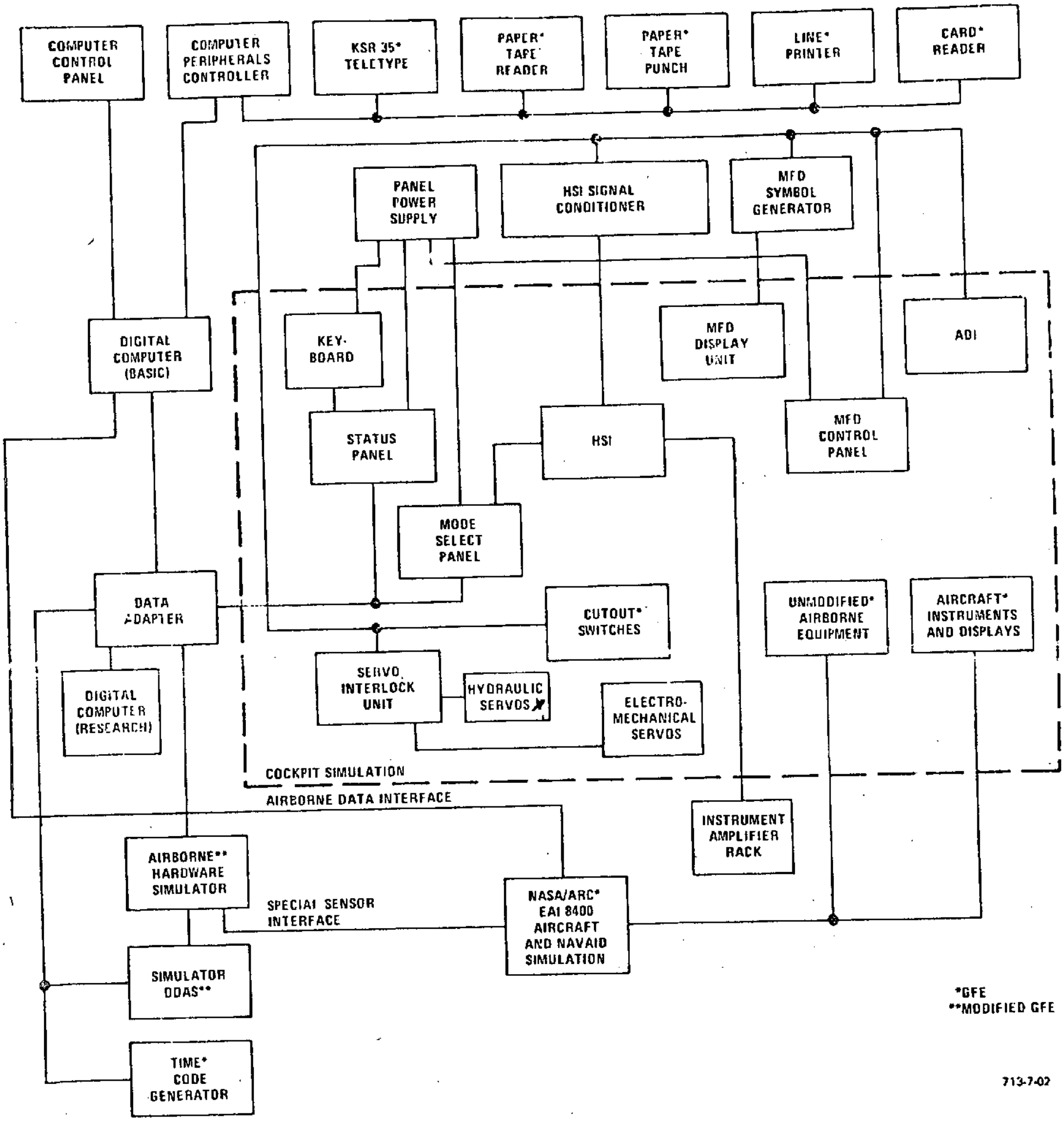
V/STOLAND shall include a 3-axis rate gyro assembly and a three-axis accelerometer assembly. Pitch and roll attitude references shall be provided by an on-board vertical gyro. Magnetic heading information shall be provided by an on-board compass system. The contractor shall provide electrical interfaces and mounting provisions for a GFE inertial navigation system in addition to the vertical gyro interfaces.

3.3.1.3 Navigation Sensors

V/STOLAND shall interface with GFE Navaids, which will include a digital VOR receiver, a DME receiver, a MODILS receiver, an ILS receiver, a



V/STOLAND Flight System Block Diagram
Figure 3.3(a)



V/STOLAND ARC Simulation Block Diagram
Figure 3.3(b)

Multilateral Ranging System (MRS) interrogator, a radio altimeter, a TACAN receiver, an ILS controller, a VOR/DME controller, a TACAN controller, and a MODILS controller. The Navaid receivers will also provide raw data to aircraft cockpit instruments (GFE). The Navaid receivers shall be mounted on the V/STOLAND pallet except as agreed upon in the Navigation Aids Interface Document (Section 3.9.3) and the contractor shall provide electrical interconnects between the controllers and V/STOLAND flight rack. Detailed requirements for V/STOLAND sensors are given in Section 3.6.2, and the interfaces shall be controlled in the Navigation Aids Interface Document.

3.3.1.4 Computer and Data Adapter

V/STOLAND shall include two airborne, programmable general-purpose 1819B digital computers which shall use all of the V/STOLAND software defined herein. One computer shall be designated the Basic Computer, and the other the Research Computer. The V/STOLAND data adapter shall interface all V/STOLAND hardware elements, except as agreed by the government, and shall interface V/STOLAND with the GFE defined in Section 3.8. Detailed requirements are given in Section 3.6.3.

3.3.1.5 Software

V/STOLAND shall include software that shall allow operation in the configurations defined in Section 3.4, providing all navigation, guidance, and control functions. The contractor shall provide a complete set of software for the Basic Computer, and I/O executive software for the Research Computer. The system performance requirements which apply to the software and hardware are given in Section 3.3.3, and detailed software requirements are given in Section 3.5. Interfaces to GFE which affect software will be defined in Section 3.9. The contractor shall provide sufficient information to allow the government to generate complete software programs.

3.3.1.6 Control Stick and Pedal Force Sensors

V/STOLAND shall include cyclic and collective control stick and pedal force sensors (on the research pilot's side) to allow implementation of "control stick steering". Detailed requirements for control stick steering modes are given in Section 3.4.5. The interface with the aircraft shall be described in the Aircraft Interface Document (Section 3.9.5). The control stick and pedal force sensors are described in Section 3.6.5.

3.3.1.7 Position Sensors

Linear position sensors (LVDT's) shall be provided for parallel actuator position sensing (three) and research pilot's collective control sensing (one).

3.3.1.8 Pilot Controls

V/STOLAND shall be operated by the pilot designated as "research pilot" and therefore only one set of V/STOLAND pilot controls and displays shall be provided except as stated in Section 3.2. V/STOLAND shall include an alphanumeric keyboard and panels containing specific buttons and switches. These controls shall allow the pilot to select guidance reference values, flight path waypoints, operating configuration, autopilot modes, control feedback gains, programmed flight path, flight director operation, display parameters, and V/STOLAND test functions and shall provide flexibility to perform other functions as they are defined. A dedicated power supply shall provide power to the cockpit-mounted V/STOLAND controls. Alphanumeric displays of selected parameters and other information shall be provided as part of the control panels. Details of the pilot contr ls requirements are given in Sections 3.4 and 3.5. Interfaces between the controls and each aircraft shall be detailed in the Aircraft Interface Document (Section 3.9.5). The research pilot station is the left seat.

3.3.1.9 Pilot Displays

In addition to the alphanumeric displays provided in the control panels, V/STOLAND shall include an Attitude Director Indicator (ADI), a Horizontal Situation Indicator (HSI), and cathode-ray-tube Multifunction Display (MFD). The MFD shall function as the primary display for V/STOLAND and shall have a symbol generator unit. Details of the display requirements are given in Section 3.6.6. Functional requirements are also described in Section 3.4 and 3.5. Interfaces between the displays and the aircraft and between V/STOLAND and the GFE displays shall be controlled in the Aircraft Interface Document (Section 3.9.5).

3.3.1.10 Aircraft Controls

V/STOLAND in the UH-1 helicopter shall include (CFE) parallel and (GFE) series actuators to drive the main rotor and the tail rotor in response to pilot commands. The contractor will define all servo characteristics. Separate command channels for each series actuator (four total) shall be provided by the Data Adapter. The Servo Interlock Unit shall provide signal amplification, power supply and interlock circuits to drive the servos and clutches. Position loop closure for the series actuators shall be provided in the Servo Interlock Unit (SIU). Rate loop closure, and position loop closure if necessary, for the parallel actuators shall be provided in the SIU. Parallel actuator position information shall be obtained by LVDT position transducers installed at the same points as the parallel actuators. Detailed requirements for the servos and the SIU are given in Section 3.6.4. The interface and V/STOLAND shall be controlled in the Aircraft Interface Document (Section 3.9.5).

3.3.1.10.1 Cyclic Control System

The cyclic control system shall include (2) parallel electromechanical trim actuators and (2) GFE electrohydraulic series actuators to control the plane of rotation of the main rotor thereby resulting in a fore/aft or lateral movement of the helicopter in response to pilot or autopilot commands through the cyclic control stick.

3.3.1.10.2 Collective Control System

The collective control system shall include a parallel electromechanical trim actuator and a GFE electrohydraulic series actuator to control the pitch of the main rotor thereby resulting in ascent or descent of the helicopter in response to pilot or autopilot commands through the collective pitch control lever.

3.3.1.10.3 Directional Control System

The directional control system shall include a parallel electromechanical trim actuator and a GFE electrohydraulic series actuator to alter the pitch of the tail rotor blades thereby providing a means of directional control in response to pilot or autopilot commands through the directional control pedals.

3.3.1.11 Equipment Mounting and Interconnection

The contractor shall be responsible for detailed design and wiring definition of aircraft racks to hold the V/STOLAND equipment; fabrication and wiring of the racks shall be the responsibility of the government. The contractor shall provide a detailed design of the instrument panel for the left side of the aircraft; fabrication will be the responsibility of the government.

The contractor shall provide a set of cables to interconnect the flight equipment racks with each other and with other equipment required in the V/STOLAND system.

3.3.1.12 Aircraft Modification and Equipment Installation

The contractor shall be responsible for the design and accomplishment of all necessary modifications to the flight research vehicle to permit installation of the V/STOLAND equipment, including antennas.

Following aircraft modification, the contractor shall be responsible for installation and checkout of all V/STOLAND equipment in the flight research vehicle.

3.3.2 Description of Peripheral Equipment and Ground Support Equipment

3.3.2.1 Ground Support Equipment (GSE)

The Contractor shall provide the following ground support equipment: (2) Computer Control Panels; Programming for preflight and diagnostic tests; Special electrical harnesses; Position sensor holding fixture; ATE Adapter Cables and Test Programs; Aircrft Installation Checkout Fixture; and Peripherals Controller. Detailed requirements are given in Section 3.7.

3.3.2.2 Airborne Hardware Simulator (AHS)

The Contractor shall modify a GFE Airborne Hardware Simulator to provide a special sensor and servo interface simulation with the NASA/ARC simulation. Detailed requirements for the AHS are given in Section 3.6.7.1. The AHS shall include electrical harness interconnects between the data adapter and the AHS, between the AHS and the simulation and between the Basic computer and simulation. The contractor shall provide an interim digital interface (hardware and software) between the V/STOLAND computer and the simulation, for use when the data adapter and AHS are not available.

Following modification, the AHS will be usable with both the V/STOLAND and STOLAND avionics systems without rewiring or further modification.

3.3.2.3 DDAS Instrumentation Unit

The Contractor shall provide for output of V/STOLAND sensor outputs to the Digital Data Acquisition System (DDAS). Signal conditioning for all analog and discrete signals shall be provided in an airborne DDAS Instrumentation Unit. Requirements for signal conditioning are given in Section 3.6.7.2.

3.3.2.4 V/STOLAND Display Simulator

The contractor shall design, fabricate, install and test the Display Simulator shown in Figure 3.3.2.4. The objective of this Display Simulator is to provide an interim simulator capability at NASA/ARC for use in defining V/STOLAND MFD display requirements prior to delivery of the complete simulation equipment shown in Figure 3.3(b). The equipment used in the Display Simulator which shall be provided by NASA/ARC is designated by an asterisk(*); all other equipment shall be provided by the contractor. The MFD Interface Unit may use spare STOLAND Data Adapter cards, but shall be designed for rapid removal of these cards in the event they are needed as flight spares. The Display Simulator shall be installed in a UH-1 laboratory simulator at NASA/ARC.

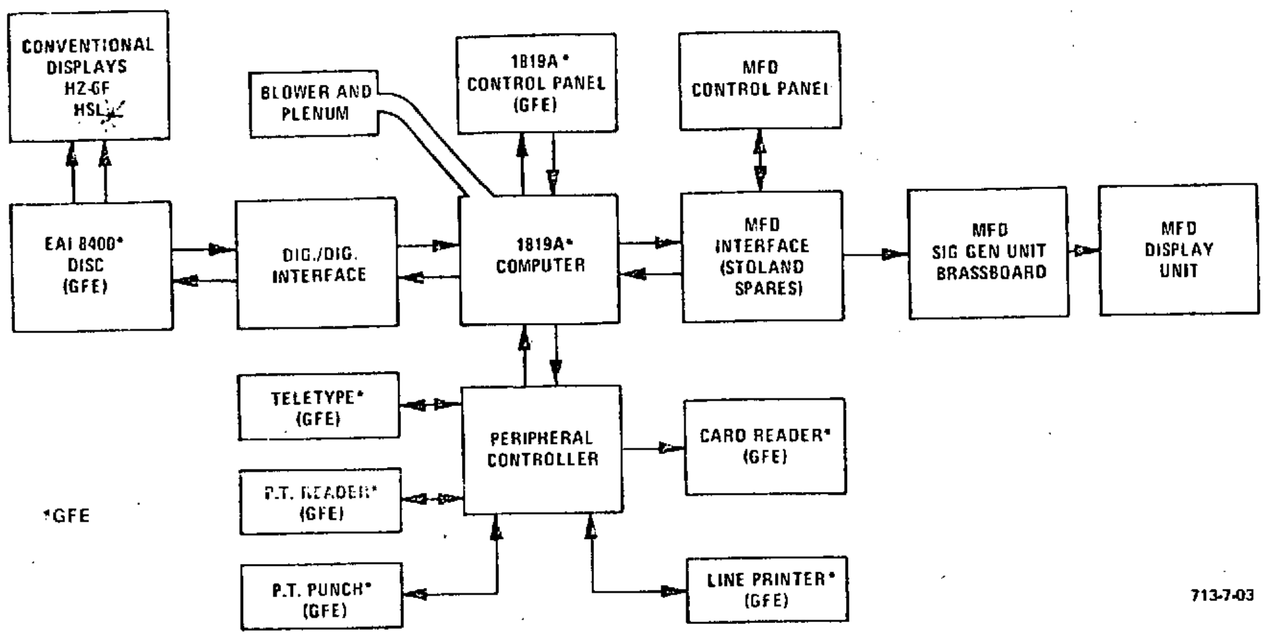
The contractor shall also provide the necessary software to generate 3 terminal approach display configurations.

The contractor shall demonstrate with all equipment operational, the capability of the Display Simulator to perform all of the functions normally required of such a facility. This functional demonstration shall include:

a. Assembly of programs from a source deck and the use of diagnostics and other programming aids.

b. Simulated flight of a V/STOLAND vehicle.

Acceptance testing shall consist of engineering and pilot approval on a qualitative basis of the functions of all applicable hardware and each of three display configurations as described in Task 10 of the Statement of Work.



Block Diagram - V/STOLAND Display Simulator
Figure 3.3.2.4

3.3.3 Performance

V/STOLAND shall be capable of navigating, guiding and controlling the V/STOLAND aircraft within the terminal area using Microwave Scanning Beam (MODILS) or Multilateration Ranging System (MRS) through an approach that will include a curved, steep, decelerating descent to a precise landing. The contractor will provide software in the Basic computer for guidance and navigation using MODILS; the government will provide software in the Research computer for guidance and navigation using MRS, and for curved, steep, decelerating descents. Approaches to the terminal area shall also be performed using TACAN or VOR/DME as the guidance aid; final approach and landing guidance will be obtained from MODILS or conventional ILS. The guidance capabilities stated in Section 3.3.3.2 shall be demonstrated by simulation when V/STOLAND is operating in any one of the configurations described in Section 3.4, on a flight path defined by Section 3.3.3.2. Simulations will also impose the weather conditions defined by Section 3.3.3.4. V/STOLAND shall be capable of controlling the helicopter from an indicated airspeed (IAS) of 120 knots down to hover.

3.3.3.1 Terminal Area Definition

For the purpose of this specification, the terminal area shall include all air space which is within 30 nautical miles of the pad and which is less than 10,000 feet above pad elevation.

3.3.3.2 Programmed Flight Paths

V/STOLAND flight paths for flight and simulator testing will be defined before each flight. One flight path shall be stored in the Basic computer for use during each flight. These flight paths shall be described in the V/STOLAND technical supplement. These flight paths shall be used for flight and simulator testing which demonstrates system performance. Each flight path shall be deined and stored in V/STOLAND by a combination of waypoint locations and analytic functions. The pilot shall be able to alter the location in 3 dimensions by means of the pilot controls described in Section 3.6.5.

3.3.3.3 Environments

V/STOLAND shall be designed to permit automatic approaches and landings under severe wind and gust conditions as defined by Appendix 7.2 of NASA/ARC Specification A16851 which shall be augmented by the contractor to include turbulence conditions during hover. This requirement shall be discussed in the V/STOLAND Technical Supplement. Gust-induced accelerations need not be smoothed to meet passenger comfort criteria. Performance of V/STOLAND under adverse weather shall be demonstrated in the simulations required by Section 4.5. Environments within the aircraft are defined in Section 4.5.1. V/STOLAND shall be designed to meet all requirements of this specification while exposed to the combined operating environments specified by Section 4.5.1 and shall be designed to operate after multiple exposures of several days each to the non-operating environments specified by Section 4.5.1.

3.4 V/STOLAND Configuration

V/STOLAND shall be capable of being operated in four flight configurations as defined herein: Auto Guidance, Autopilot, Flight Director and Manual, and shall also have a Calibration/Checkout configuration. All software for the first four configurations shall be located in the Basic computer. The Calibration/Checkout configuration uses preflight test software which is located in the Research computer. Other Research computer software will contain experiments, and is called up by depressing the "RES MODE" pushbutton on the MFD Control Panel. In the Auto Guidance configuration defined in Section 3.4.1, V/STOLAND shall automatically navigate, guide, control and land the aircraft. The other flight configurations, as defined in Sections 3.4.2, 3.4.3, and 3.4.4, shall provide capabilities equivalent to less sophisticated guidance and control systems. The pilot shall be able to switch between configurations in flight. While V/STOLAND is in either Flight Director or Manual configuration (Section 3.4.3, 3.4.4) the pilot shall be able to engage or disengage Control Stick Steering modes (CSS) defined in Section 3.4.5. The pilot shall be able to switch from an automatic configuration to a CSS-aided manual configuration by engaging the CSS switch, which in turn will cause the "Auto" switch to disengage. V/STOLAND shall be operable in flight by one pilot (research pilot). A single set of V/STOLAND controls and displays shall serve for all configurations. The information presentation shall be automatically changed when the configuration is changed in order to provide the display appropriate to the selected configuration. The pilot shall be able to select other preprogrammed display formats when in "Research" mode.

V/STOLAND shall nominally use MODILS for guidance. Outside the MODILS range, TACAN or VOR/DME shall be used. Receiver tuning shall be performed manually by the research pilot. Switching between VOR/DME or TACAN and MODILS shall be automatic if the NAV Source Select switch on the MSP is in "Auto" position. V/STOLAND shall provide a smooth transition between navigation aids.

Other navigation aids, such as MRS and INS, will be available in Research configuration.

The locations and detailed operation of the controls referred to in this section shall be controlled by Section 3.6.5. Display operation is more fully described in Section 3.6.6.

3.4.1 Auto Guidance

V/STOLAND shall be set in the Auto Guidance configuration by moving the Mode Select Panel servo engage switch to "Auto" and by depressing the "Auto Guid." pushbutton. Initialization on the flight path shall be as described in Section 3.5.3. The pilot shall maneuver the aircraft to within capture limits. The "Auto Guid." button shall light amber until capture of the flight path. After capture of the flight path, the button shall light green and V/STOLAND shall thereafter automatically navigate, guide, and control the aircraft within the terminal area through approach and touchdown along the selected flight path. Maneuvers, from cruise to landing (V/STOL), shall be coordinated by positioning the main rotor tilt and blade pitch, the tail rotor blade pitch, and the position of the synchronized elevator. Navigation, guidance, and control design requirements are given in Section 3.5.

The research pilot shall be able to monitor V/STOLAND performance on the displays. He shall be apprised of predicted flight path in relation to selected flight path, present errors from the selected flight path in two dimensions, and V/STOLAND malfunctions. The MSP buttons and displays shall indicate automatic arming, engaging and disengaging of the autopilot modes. If Flight Director is selected, the flight director indicators shall show pilot guidance information to the selected flight path. Detailed display requirements are given in Section 3.6.6.

If the research pilot maneuvers the aircraft outside the flight path capture limits or if the automatic control is unable to fly to the flight path, "Auto Guid." shall go off. In the event of detected failure or loss of navaid data V/STOLAND servos shall disconnect or V/STOLAND shall enter a safe set of control modes.

V/STOLAND shall automatically disconnect if a fault is discovered during self-check. If the automatic disconnect fails, application of force by the research pilot to levels agreed upon between the contractor and government shall cause autopilot and servo disengagement. The V/STOLAND servo shall be fitted with clutches that will allow either pilot to overpower the V/STOLAND control in the event of failure to sense the disconnect force level. Either pilot shall also be able to disengage all V/STOLAND servos by means of the V/STOLAND cutout switch on each cyclic pitch grip. Emergency cutout, force takeover, or automatic disconnect shall not shut off navaid receivers and controllers, attitude references, the Flight Director or the HSI: these devices shall continue to provide basic data to the pilot. The "V/STOLAND Disconnect" warning lights (Section 3.6.6.6) shall light for any of the above disconnects except pilot actuation of the V/STOLAND cutout switches. Shutting off functions by means of the MSP switches shall not light the disconnect warning lights.

3.4.2 Autopilot

This configuration is selected by moving the "AUTO" switch on the Mode Select Panel to the engaged position. That action will engage the basic autopilot modes of pitch attitude hold and heading hold. The control stick steering modes of Section 3.4.5 are available to the research pilot in this configuration, as well as all of the autopilot modes of Section 3.4.2.1.

3.4.2.1 Autopilot Modes

V/STOLAND shall provide the autopilot modes described herein as functions of software in the Basic computer. The research pilot shall be able to call any safe combination of lateral or longitudinal modes. Each mode shall provide for automatic trim of the aircraft. All modes, unless specified otherwise, shall be operable in both cruise and V/STOLAND (landing) aircraft configurations. Each mode shall operate the aircraft controls including collective pitch, cyclic pitch, and the directional controls as appropriate to the aircraft configuration. Normal acceleration and attitude rate limiting shall be used to provide smooth operation. When "AUTO" operation is commanded, V/STOLAND shall automatically enter the Pitch Attitude Hold mode.

Autopilot modes, except Heading Hold as described below, shall go off when the pilot maneuvers outside capture limits. If a fault is discovered by V/STOLAND self-check, the servos shall disconnect and the "V/STOLAND DISCONNECT" warning light shall flash. Application of force levels agreed upon between the contractor and the government shall cause disengagement of the V/STOLAND servos and autopilot. The V/STOLAND cutout switch shall disengage the V/STOLAND servos and autopilot.

If roll angle is less than 5 degrees, Heading Hold shall automatically be initiated. If roll angle is greater than 5 degrees, Roll Attitude Hold shall automatically be engaged.

3.4.2.1.1 Pitch Attitude Hold

This mode shall be automatically engaged when "AUTO" operation is initiated. The aircraft pitch attitude shall be maintained at the attitude extant at the time of initiation.

3.4.2.1.2 Heading/Roll Angle Hold

This mode shall be automatically engaged when the "Auto" switch is selected. If the roll angle is less than 5 degrees, Heading Hold shall be engaged. When the roll angle is greater than 5 degrees, Roll Angle Hold shall be engaged. V/STOLAND shall maintain the roll angle by coordinated control operation. V/STOLAND shall limit roll angles to within safe aircraft operating limits. When a roll angle is being held, the "HDG HLD" button light shall go out.

3.4.2.1.3 Heading Select

The pilot shall be able to select a desired heading by means of the Heading slew switch and by selecting this mode, the aircraft shall be maneuvered to smoothly capture the selected heading. After capture, this mode shall switch to Heading Hold.

3.4.2.1.4 Indicated Airspeed (IAS) Modes

These modes shall be engaged by the "IAS HLD" and "IAS Select" buttons on the MSP. Airspeed shall be controlled to the existing value at initiation of the mode or to the selected value by means of pitch attitude changes.

3.4.2.1.5 Flight Path Angle Modes

These modes shall be selectable to control flight path angle within safe limits. The Flight Path Angle Hold Mode may be used with the Altitude Select mode; in this case the pilot-selected flight path angle shall be held instead of the angle selected automatically by the Altitude Select mode. Upon capture of the selected altitude, Flight Path Angle Hold shall disengage. If conflicting commands are given, the last mode selection shall prevail and the previous selection shall drop out.

3.4.2.1.6 Altitude Modes

These modes shall be selectable by means of the "ALT HLD" and "ALT SEL" buttons on the MSP. The select function shall smoothly maneuver the aircraft into a safe ascent or descent as appropriate to the aircraft, airspeed, etc. to smoothly capture the selected altitude. If a flight path angle has been engaged by "FPA HLD", the flight path angle shall be held until altitude capture. Altitude modes shall be referenced to best estimated altitude, derived primarily from barometric altitude.

3.4.2.1.7 Navaid Radial Guidance

Automatic guidance and control along a VOR or TACAN radial shall be selectable by the pilot. The radial bearing shall be selectable by the course slew switch on the MSP. Depressing the "TAC" or "VOR" lateral guidance pushbutton shall enable smooth capture of the selected radial when the aircraft is maneuvered to within capture limits defined by the contractor. When selected, the "TAC" or "VOR" lateral guidance pushbuttons shall illuminate amber when the data valid indicates valid and shall light green when the airplane has been guided to within the capture limits of the selected radial. When the data valid indicates invalid, the modes shall not arm (no lights). Tuning of the navaids shall be performed manually by means of the GFE navaid controllers. Loss of the data valid shall disengage the mode and V/STOLAND shall enter Heading/Roll Angle Hold mode.

3.4.2.1.8 Waypoint Radial Guidance

The pilot shall be able to select guidance and control along a selected radial to a computer-generated waypoint. To accomplish the guidance and control, he shall select a waypoint by means of the keyboard and a radial by means of the MSP Course Select (CRS) knob. Depressing the "WPT" pushbutton will cause it to light amber until capture criteria are met. Thereafter, operation will be the same as described in 3.4.2.1.7 for navaid radial guidance.

3.4.2.1.9 Land

This mode shall be selected by the MSP "Land" pushbutton. If a valid MODILS or ILS signal is present, the pushbutton shall light amber indicating an armed state. When the aircraft is guided to within the capture range V/STOLAND shall guide and control the aircraft to smoothly capture and track the glideslope and localizer. The glideslope and expanded localizer deviation indicator shall display deviation from the beam. Once the localizer has been captured the mode shall not be disengaged by selection of any other pushbutton until the pilot applies overpower force or data valid is lost. If data valid is lost, V/STOLAND shall automatically enter the Altitude Hold mode and Heading Hold mode.

3.4.3 Flight Director (F/D)

This configuration shall be defined by selection of only Flight Director by means of the "FLT DIR" button on the MSP. The control-stick steering modes shall be activated by the "CSS" switch if desired by the pilot. In normal operation, the pilot will select automatic flight director guidance to one of the modes described in 3.4.3.1.

3.4.3.1 Flight Director Operation

The flight director modes described herein shall provide guidance commands to the pilot derived from flight director analytical laws. Command presentation shall not require uncoordinated controls, abrupt control deflections, control beyond safe operating conditions, or response time less than that for good human engineering practice. When both the Flight Director and Autopilot functions have been selected, the Flight Director commands shall provide a means of monitoring the autopilot operation.

When the flight director modes are used individually, operation of the MSP slew switches in conjunction with the associated MSP "Hold" and "Select" buttons shall be the same as for the autopilot modes (Section 3.4.2.1). The MSP displays shall remain at the readings extant at initiation of Flight Director operation, until changed, and shall not flicker or change without pilot action. The MSP display windows shall continue to display the selected value of the function, even if the pilot deviates from that value, until the pilot actuates the button off. For all modes, a second actuation of the button shall turn the mode off. The mode interlocks shall be defined such that only a single mode shall control operation of each separate flight director indicator. Initial selection of Flight Director shall automatically activate the Heading Hold mode at the existing setting. Heading Hold shall remain on until superseded or turned off by pilot selection.

3.4.3.1.1 Heading Modes

Same as 3.4.2.1.2 except that the Flight Director vertical command bar shall display guidance information to a selected heading reference.

3.4.3.1.2 Indicated Airspeed Modes

Same as paragraph 3.4.2.1.4 except that the guidance information to the selected IAS shall be presented by means of the Flight Director horizontal command bar.

3.4.3.1.3 Flight Path Angle Modes

Same as paragraph 3.4.2.1.5 except that the guidance information to the selected flight path angle shall be presented by means of the Flight Director collective command display.

3.4.3.1.4 Altitude Modes

Same as paragraph 3.4.2.1.6 except that the guidance information to the selected altitude shall be presented by means of the Flight Director collective command display.

3.4.3.1.5 Navaid Radial Guidance

Same as paragraph 3.4.2.1.7 except that the Flight Director vertical command bar will be utilized to guide the pilot to and along a radial selected by means of the "Course" slew switch.

3.4.3.1.6 Waypoint Radial Guidance

Same as paragraph 3.4.2.1.8 except that guidance information is presented on the Flight Director vertical command bar.

3.4.3.1.7 Land

Same as paragraph 3.4.2.1.9 except that loss of valid data shall result in GS flag appearing and expanded localizer display is biased out of view.

3.4.4 Manual

This configuration shall provide data on the V/STOLAND displays which is typical of that available from simple, economical avionics systems. When no other configurations have been selected, V/STOLAND shall be in manual mode.

The pilot shall use the MSP heading and course slew switches to control the HSI settings. He shall be able to select a navaid (TACAN, VOR, or LAND) by means of the Mode Select Panel selector switches and obtain deviation information on the appropriate ADI and HSI indicators. Operation of the navaid buttons and button lights shall be the same as for Auto and F/D. The pilot shall tune navaids manually.

While V/STOLAND is operating in Auto or F/D, actuation of the V/STOLAND internal monitors, pilot cutout switches or pilot force takeover shall cause V/STOLAND to revert to manual configuration, but navaid selections shall not change as a result of such action. If CSS modes (Section 3.4.

have been selected, they shall go off only in the event that a fault is detected in CSS-associated portions of the system or if the pilot cutout switches are actuated.

3.4.5 Control Stick Steering (CSS) Mode

The CSS mode shall be automatically engaged by setting the Mode Select Panel switch to "CSS". The control stick force sensor is described in Section 3.6.5.4. Actuation of the cutout switch shall disengage the CSS mode. The Contractor, in the delivered software program, shall insure that the CSS mode will initially be selected by the CSS switch. When CSS is operating, the manual Trim switch on the pilot's control wheel shall not operate aircraft trim controls. This inhibit shall be under software control.

3.4.5.1 CSS Modes

One longitudinal and one lateral mode shall be defined and programmed by the contractor. Design of the modes shall emphasize good handling qualities. These modes shall be selected by placing the MSP switch in "CSS".

3.4.5.1.1 Pitch Attitude Command

The pitch attitude command mode shall allow the pilot to command pitch attitude in proportion to cyclic pitch control stick force. Upon release of the force, pitch attitude shall return to the previous value. The characteristic of pitch attitude versus stick force shall be preset and shall be adjustable in flight through the pilots' keyboard.

3.4.5.1.2 Roll Attitude Command

The roll attitude command mode shall allow the pilot to command roll attitude in proportion to cyclic roll control stick force. Upon release of the force, the aircraft shall roll to level and hold heading. The characteristic of roll attitude versus stick force shall be preset and shall be adjustable in flight through the pilots' keyboard. Turn coordination shall be provided when IAS is greater than 30 knots.

3.4.5.1.3 Altitude Rate Command

The altitude rate command mode shall allow the pilot to command altitude rate in proportion to collective control stick position.

3.4.5.1.4 Yaw Rate/Heading Hold

This mode shall allow the pilot to command yaw rate in proportion to rudder pedal force. With no pedal force applied, Heading Hold mode shall be engaged.

3.4.6 Calibration/Checkout

The Calibration/Checkout configuration shall allow V/STOLAND to be calibrated and checked out while the aircraft is on the ground. Ground support equipment (GSE) shall be used to assess the readiness of V/STOLAND for flight operations. This configuration is engaged by depressing the guarded "Preflight Test" pushbutton on the Status Panel. The preflight test program normally is located in the Research computer, but can be displaced prior to flight by the Research computer airborne program if the core is required.

3.4.7 Research

This configuration is engaged, provided proper pre-conditions have been met, by depressing the "RES MODE" pushbutton on the MFD Control Panel. Mode engagement shall be indicated by green illumination of the push-button.

This configuration puts the Research computer software in control of selected portions of the system. Portions of the Basic computer software will also be used as required by the particular experiment being performed.

3.5 Software

The contractor shall provide software for the Basic general-purpose digital computer described in Section 3.6.3 to control all functions except those which are specifically identified as hardware functions elsewhere herein. Software shall be modular so that navigation, guidance, control, input/output and other modules and sub-modules may be individually changed without affecting other modules and without redesign of the executive.

Hardware and software design shall provide computation cycles which can call software routines 1, 2, 10, 20, and 40 times per second. These cycles shall be controlled by the clock reference described in Section 3.6.3.1.

Software design, including program language, shall be described by the contractor in sufficient detail to enable the government to prepare, check out and use their own software in V/STOLAND (Section 3.9.1). A user's guide shall be prepared for the Research computer.

The Contractor shall provide preflight test executive, and I/O software for the Research computer which exchanges data between computers 40 times per second. All input data to the Basic computer under software control shall be read in 40 times per second.

3.5.1 Executive Routine

An executive routine, which schedules and selects the other routines and which responds to automatic and pilot interrupts, shall be provided in the Basic computer. This routine shall be structured to facilitate use of the Research computer software without requiring revalidation of the Basic computer software.

The Basic computer shall perform all of its computations regardless of whether Research mode is engaged. During Research mode, the Basic computer will accept selected computation results from the Research computer and use them in place of its own computation results, thus allowing the desired experiments to be performed.

An executive routine shall also be provided in the Research computer which shall schedule and select the other routines used in the Research mode.

3.5.2 Navigation

The aircraft state shall be determined in 3 spatial dimensions and 3 velocities to allow performance of navigation to the flight path described by Section 3.3.3.2.

A data validation routine shall reject navigation data which is outside tolerance limits. Tolerance limits are determined by the 3-sigma value of the navaid error model; navaid error shall be computed as the difference between the navaid raw data and the output of the navigation filters.

Air data computations shall be provided for in the software. Wind vector shall also be computed. The basic navigation strategy shall use dead reckoning updated by navigation aid data. Filtering of navaids shall be used to enhance navigation accuracy. Provisions for automatic tuning of navaids shall not be provided. V/STOLAND shall normally use single VOR/DME or TACAN for area navigation. MODILS supplemented by radio and baro altimeters shall be the inputs for approach and touchdown.

V/STOLAND shall be designed to operate with a minimum scan rate of MODILS of five (5) per second.

3.5.3 Guidance

The Contractor shall generate guidance laws for both flight director and automatic operation, and the software implementation thereof, to guide the aircraft along the test flight path defined in Section 3.3.3.2. Flight path segments shall be generated to enable the aircraft to capture the flight path in 3 dimensions. Input of sets of waypoints (up to 5) by the pilot via the keyboard shall result in calculation by V/STOLAND of a new ground track flight path in 3 dimensions. Guidance requirements that require performance beyond aircraft safe limits shall result in warning to the pilot, and shall be inhibited from providing commands to the aircraft control.

3.5.3.1 Lateral Guidance

Lateral Guidance shall be provided for the reference flight path. Two alternate methods of lateral guidance shall be provided:

Method A - Shall be with respect to specified 3D flight paths where the curved paths are specified by start and finish waypoints (x, y, z) and radius of curvature.

Method B - Shall be with respect to specified 3D flight paths defined by straight line segments connecting waypoints (x, y, z) except during curved portions connecting the line segment; these shall be defined by fixed bank angle turns.

3.5.3.2 Vertical Guidance

Vertical Guidance shall be provided for the reference flight path. For vertical guidance, with respect to a specified 3D flight path, the flight path angle shall be defined by:

a. The horizontal radius of curvature

b. The altitude difference between consecutive waypoints (x, y, z)

Consecutive waypoints must be defined such that they can be connected by a turn of less than 2 π radians. The only exception to this statement is that during transition between paths requiring different flight path angles, the path shall be defined by appropriate acceleration constraints.

3.5.3.3 Initialization on Flight Path

V/STOLAND shall be capable of entering a programmed flight path at any waypoint which is at the beginning of a straight segment. The segment can have any flight path angle.

To enter the flight path, the pilot shall enter the number designation of the desired entry waypoint by means of the Keyboard. The pilot shall then maneuver the aircraft to intercept the backward extension of the line connecting the entry waypoint with the succeeding waypoint. The intercept shall be a distance of no less than one aircraft turning radius from the entry waypoint, and the vertical error shall be less than ±500 feet. V/STOLAND shall automatically capture the flight path extension, using lateral and longitudinal modes for 3D guidance.

3D guidance will terminate at the point designated "WPT_F" on the flight path. Upon reaching WPT_F, the flight path program will automatically reset so that the next initialization would take place at the point designated by the pilot. Selection of any configuration that requires 3D guidance will automatically initialize the flight path at the point selected by the pilot by means of the keyboard.

3.5.4 Aircraft Control

The contractor shall generate control laws for the control modes defined in Section 3.4.2.1 and 3.4.5. The contractor shall provide software implementation of the control laws. The V/STOLAND software shall provide, in the Auto Guidance configuration, for automatic calling of the appropriate control mode routines, singly or in combination, to effect guidance of the aircraft along the selected flight path with minimum error.

3.5.4.1 Command Limitations

Mode interlocks and limitations shall be provided to prevent acceptance of conflicting commands or commands which would result in aircraft performance beyond safety limits. Sections 3.4.2 and 3.4.3 describe some of the required interlocks. Safety - Critical Interlocks shall be provided in hardware as described in Section 3.6.4. A comprehensive description of the interlocks is presented in the V/STOLAND Technical Supplement

3.5.4.2 Control Gains

The Contractor shall provide for easy modification of control feedback gains to facilitate adjustment to use V/STOLAND on other aircraft and in the event that the primary aircraft control requirements change due to aircraft modification. In addition, the contractor shall provide limited adjustment of gain in flight by means of the pilot's keyboard.

3.5.5 Pilot Control Interface

Software shall provide for acceptance, addressing and execution of pilot commands. Pilot navigation commands shall be in orthogonal coordinates, referenced to the center of the landing pad.

3.5.6 Data Output

Software shall provide for output of the data required for monitor/record of V/STOLAND performance to the Digital Data Acquisition System.

3.5.7 System Self-Check

Two check routines shall be provided for.

3.5.7.1 Computer Monitoring

Failure monitoring of the computer shall be achieved by sampling of the BITE-TEST-IN-PROGRESS (BTIP) discrete signal line in the Servo Interlock Unit (SIU). The computer Input/Output section shall also be monitored in the software via comparisons of certain data words that have been transferred to and from the Data Adapter. If the software monitor trips, the BTIP line shall be dropped, indicating that the computer (software) is invalid.

3.5.7.2 Preflight System Test

This program shall provide a standard means for verifying system performance within predetermined limits as required by Section 4.5.4.4. Program input from peripheral equipment (3.6.7) shall be possible, but the program shall be resident in the Research computer. To the maximum extent possible, faults shall be isolated to the line-replaceable unit (LRU) level. The test shall be programmed so that parts which test simulated equipment can be skipped over by the operator through use of the "Test Skip" pushbutton on the Status Panel.

This program can be displaced before flight if the core is needed for the Research computer airborne program.

3.5.8 Verification and Validation

All software routines shall be verified during the systems tests at the contractor's plant defined in Section 4.5. Validation of performance in ARC simulation will be the acceptance criteria. The programming thus validated will be used for the flight acceptance test. Validation Criteria shall be defined by the Contractor in the V/STOLAND Technical Supplement.

3.5.9 Simulation

Simulator software shall be identical to flight software except for inclusion of program stop-start subroutines to allow "holding" th simulation without disrupting program sequence and shall provide for operation independent of the NASA simulation computer. Software to be validated shall be identical to the flight software.

3.6 V/STOLAND Hardware

3.6.1 System

The requirements specified in this section apply to V/STOLAND, including GFE. The functional relationships of V/STOLAND are shown in Figure 3.3. The requirements are applicable to all configurations defined in Section 3.4 unless noted otherwise. It is anticipated that the MFD Control Panel, Mode Select Panel, Keyboard, and Status Panel that were designed for STOLAND can be applied directly to V/STOLAND with either no changes or minor changes with respect to circuitry and physical layout.

3.6.1.1 Pilot Control

In automatic or CSS operation, either the research pilot or the safety pilot shall have the capability to overpower the V/STOLAND control and shall have the capability of disconnecting the V/STOLAND control via the control stick cutout switches or the Auto switch (all shall be hardware provisions). In addition, the computer interlock and monitor routine shall disconnect V/STOLAND servos when the pilot force exceeds a threshold to be established by agreement between the contractor and the Government. The threshold level for each axis shall be identified in the Aircraft Interface Document (Section 3.9.5).

3.6.1.2 Flight Safety

No single failure of V/STOLAND shall result in an unsafe condition or unsafe maneuver of the aircraft. In the automatic configurations, controls shall be automatically trimmed as necessary to prevent requirements of large pilot forces in the event of emergency cutout of V/STOLAND. In addition, aircraft failures shall not interact with V/STOLAND to cause an unsafe condition or maneuver which would not otherwise have occurred.

3.6.1.3 Emergency Conditions

V/STOLAND shall not be required to compensate for aircraft malfunctions or emergencies, except as required by Section 3.6.1.2.

3.6.1.4 Maintainability

The contractor shall assure that V/STOLAND and its components can be maintained with a minimum of down time. Modularization of parts or components shall be used. Replaceable parts shall be mounted and connected in a reliable manner. Maintainability requirements are given in NASA Document NHB5300.4(1A). Maintenance requirements shall be given in the Maintenance Plan required by the contract.

3.6.1.5 Equipment Lifetime

The V/STOLAND equipment shall be designed for a minimum lifetime after delivery of two years, and shall be protected against corrosion, humidity, temperature and handling commensurate with that period.

3.6.1.6 Operating Time

The V/STOLAND equipment shall be designed for a minimum operating time, without line-replaceable unit replacement or scheduled maintenance, of 2,000 hours during the two-year lifetime required by Section 3.6.1.5.

3.6.1.7 Electromagnetic Interference (EMI)

The V/STOLAND shall be designed to meet the requirements of, and EMI limits provided by, MIL-STD-461A. V/STOLAND equipment shall be generally classified ID per MIL-STD-461A unless otherwise agreed upon. Specific requirements for the grounding, bonding and interconnection of components which shall apply to the V/STOLAND design are contained in Appendix 7.3 of Specification A-16851. AFSC DH 1-4 shall be used as a reference source of design and analytical techniques. Equipment used in V/STOLAND, for which documented evidence of conformance to MIL-STD-461A limits are provided to NASA-Ames, need not be redesigned. No EMI testing is required for V/STOLAND, but any malfunction, incorrect data display or guidance error outside specified limits due to radiated or conducted interference or to static charge buildup in the aircraft shall constitute unacceptable performance. The digital computer shall be especially protected against EMI. Program scrambling or extraneous outputs as a result of EMI shall be unacceptable. (See Section 4.5.1.5 for aircraft-created EMI environment.) The contractor shall assist the Government until completion of flight acceptance test in determining the source of malfunctions. The Government will be responsible for elimination of EMI generated by the aircraft above the levels specified herein.

3.6.1.8 Electrical Grounding

Electrical grounding shall meet the requirements of both Sections 3.6.1.6 and 4.3.

3.6.1.9 Electrical Connector Caps

All unmated electrical connectors shall be fitted with protective caps designed to protect the pins from damage or dirt and to protect personnel from electrical shock.

3.6.1.10 Surface Coatings

All exposed surfaces of the equipment shall be painted or coated with protective finishes. Such coatings shall not flake or peel under normal use. Cockpit equipment shall have nonreflective finishes.

3.6.1.11 Moisture Protection

Equipment shall not malfunction when exposed to the humidity environments given in Section 4.5.1. Hermetic sealing of component cases shall not be employed unless the sealed component cases can be demonstrated to maintain the seal under crushing and burst pressures of 2.0 times the maximum/minimum pressures given in Section 4.5.1 and unless maintainability is not compromised.

3.6.1.12 Peripheral/Ground Support Equipment

Failure or short circuit of checkout, peripheral or ground support equipment shall not cause damage to V/STOLAND. Peripheral equipment which is connected to V/STOLAND in flight shall meet the same safety and reliability requirements as STOLAND.

3.6.1.13 Size and Packaging

Packaging of V/STOLAND and its components shall be planned for easy maintenance. The size, shape, and location of V/STOLAND and its cable connections shall be rigidly controlled as part of the Aircraft Interface (Section 3.9.5). The total volume of the airborne V/STOLAND, including GFE navaids, shall not exceed 120 cubic feet and the maximum dimensions of each of two airborne pallets shall not exceed 48 inches high, 32 inches deep, and 56 inches wide. Location of the controls and displays shall be identified in the Aircraft Interface Document. V/STOLAND, except for pilot controls, displays, control servos, gyros, and accelerometers shall be installed in 2 self-contained pallets, which shall include cooling air as required. The LTN-51 INU, accelerometers, and rate gyro assemblies shall be mounted on a separate rack (3.6.2). Dimensions of the inertial sensor rack shall not exceed 15" width, 25" length, and 24" height. Nonflight V/STOLAND shall be mounted in a rack for convenience.

3.6.1.14 Weight

The maximum weight of the total airborne V/STOLAND and peripheral equipment including mounting brackets and government-furnished equipment, shall not exceed 1400 pounds. Center of gravity and mass distributions (moments of inertia) shall be controlled in the Aircraft Interface (Section 3.9.5). The actual mass of each component and the running weights of cables shall be accounted for and included in the Aircraft Interface Document. The Government will provide the weights of GFE.

3.6.1.15 Power

The power requirements for V/STOLAND equipment including GFE navaids shall be defined. The government will provide the power requirements for GFE. The power interface shall be controlled as part of the Aircraft Interface defined by Section 3.9.5, and definition of the aircraft power available will be provided therein.

3.6.1.16 Vibration Isolation

The contractor may elect to include vibration isolation to meet the environments specified in Section 4.5.1. Such isolation shall be included in the package or pallet.

3.6.2 Sensors and Navigation Aids

All inputs to V/STOLAND not specifically mentioned hereunder shall be obtained from government-furnished equipment (Section 3.8). The interfaces with V/STOLAND will be described in the Navigation Aids Interface Document (Section 3.9.3) or in the Aircraft Interface Document (Section 3.9.5) as appropriate.

The government shall provide mounting brackets for air data sensors, and a "platform" for mounting the inertial sensors. The platform, which shall be designed by the contractor, shall contain provisions for convenient alignment of the sensors. The contractor shall install and align the platform in the aircraft.

3.6.2.1 Air Data

True airspeed measurements shall be obtained from a GFE sensor and static pressure transducer measurements shall be obtained from contractor-furnished equipment. Interface provisions including location shall be controlled in the Aircraft Interface Document (Section 3.9.5). The Air Data sensors shall meet the requirements given in Table 3.6.2.1.

TABLE 3.6.2.1

AIR DATA SENSOR CHARACTERISTICS

Characteristic	Static Pressure Transducer	Airspeed Transducer
Range	-100 to 10,000 feet	0 - 200 knots TAS
Accuracy	±15 feet	1 percent of F.S.
Resolution	0.4 foot at sea level; 0.5 foot at 10,000 feet	0.1 knot
Response Time	20 milliseconds	100 milliseconds

Temperature data required for calibration of the static pressure transducer shall be provided by a sensor integral to the transducer. Temperature data shall be in analog form and shall be digitized in the data adapter; temperature calibration shall be performed automatically by the digital computer program.

3.6.2.2 Stabilization and Control Sensors

3.6.2.2.1 Rate Gyro Assembly

V/STOLAND shall include a pitch rate gyro assembly and a yaw/roll rate gyro assembly which shall have the following characteristics:

Characteristics	Pitch	Yaw	Roll
Gain tolerance (-55°C to +71°C), percent	±4	±4	±4
Cross-axis sensitivity, deg/sec/deg/sec	0.01	0.01	0.01
Scale factor, millivolt/deg/sec	250	250	250
Maximum threshold, deg/sec	0.04	0.04	0.04
Resolution, deg/sec	0.04	0.04	0.04
Zero offset, deg/sec	0.2	0.2	0.2
Linearity, percent full scale	±0.5 to 1/2 scale, ±2.0 to full scale		
Hysteresis, deg/sec	0.06 max	0.06 max	0.06 max
Static Balance, deg/sec/g	0.05	0.05	0.05
Null (-55°C to +71°C), mV	80	80	80
Range, deg/sec	40	40	40

The rate gyros shall have built-in self-test capability consisting of a Spin Motor rotation detector (SMRD), and a self-test torquer. The assembly shall include SMRD decoding, speed detection circuitry and demodulators for rate gyro signals. The STOLAND Rate Gyro Assemblies shall function as acceptable spare assemblies.

3.6.2.2.2 Accelerometer Assembly

V/STOLAND shall include a three-axis linear accelerometer assembly. The accelerometer shall be of the closed-loop, pendulous, force-balance type. The accelerometers shall have the following characteristics:

Characteristics	Normal (1g bias)	Lateral and Axial
Linear Range, g	-1.0 to +4.0	±1.0
Null Output, mV	±30	±80
Scale Factor, volts/g	2	5
Scale Factor Tolerance, percent full scale	0.25	0.25
Temperature coefficient of scale factor, percent/degree C	±0.02	±0.02
Threshold, g	<0.005	<0.005
Hysteresis, percent full scale	<0.1	<0.1
Cross Axis Sensitivity, g/g	<0.005	<0.005

The assembly shall provide self test over the full operating range to an accuracy of ±5 percent. The STOLAND accelerometer assembly is an acceptable spare assembly.

3.6.2.2.3 Vertical Gyro Assembly

V/STOLAND shall include a GFE vertical Gyro Assembly, Type MD-1.

3.6.2.3 Navigation Sensors

The GFE Navaids will include: Digital VOR Receiver, DME Receiver, VOR/DME Controller, TACAN Receiver, TACAN Controller, MODILS Receiver, MODILS Controller, MRS Interrogator, Radio Altimeter, VHF Nav (for ILS) Receiver, VHF Nav (for ILS) Controller, INS Inertial Navigation Unit, INS Interface Unit, INS Control/Display Unit, INS Mode Selector Unit, and IIS Control Head. Antennas for these navaids will also be GFE on the aircraft. The contractor shall provide the following: Yaw/Roll Rate Gyro Assembly, Pitch Rate Gyro Assembly, Accelerometer Assembly, and Static Pressure Transducer. Interfaces will be controlled in the Navigation Aids Interface Document (Section 3.9.3), and the Aircraft Interface Document (3.9.5). The navaid receivers shall be mounted in the V/STOLAND pallet except as agreed to in the Navigation Aids Interface Document. The contractor shall provide electrical harness between the receivers and the Navaid controllers. The contractor shall provide a relay in the power lines to the VOR/DME controller to allow the pilot to turn receiver power on or off at the controller. Controller and antenna mounting shall be the contractor's responsibility.

3.6.3 Computer and Data Adapter

V/STOLAND shall include two (2) general-purpose airborne digital computers, each with 16,384 words of 18-bit memory. One computer shall be designated the Research Computer, and shall be programmed by the government except for preflight test, executive, and I/O routines, which shall be provided by the contractor.

The other computer, called the Basic computer, shall be programmed by the contractor to provide the following functions:

Data interchange with Research computer.

Basic autopilot, attitude stabilization, and maneuvering control law computations.

Mode interlocks.

Navigation and state estimation computations including use of various sensors.

Display computations including MFD displays.

Air data computations.

Data logging including in-flight parameter monitoring.

Failure detection, status monitoring, and fault isolation.

Miscellaneous flight management functions.

3.6.3.1 Digital Central Processing Unit

Details of the central processing unit are described in the Equipment Specification for 1819B Digital Computer, Sperry Specification X4019719.

3.6.3.2 Data Adapter

The data adapter shall provide all necessary controls and signal conditioning for information transfers to/from the digital computer. It includes signal conditioning circuitry to process the airborne sensor signal inputs and control outputs to the V/STOLAND system. The data adapter includes the necessary circuitry to accomplish multiplexed analog-to-digital input conversions, digital-to-analog output conversions, and digital-to-digital input and output conversions. The digital data adapter shall provide the following basic capabilities and growth provisions.

3.6.3.2.1 Analog-To-Digital Converter

A 12-bit successive approximation-type converter shall be used with an accuracy of ±0.1 percent of full scale (±10 volts) and a throughput rate of 250 microseconds/word including computer input time. Value of least significant bit is 5 millivolts.

3.6.3.2.2 Discretes

Input capability for 96 +15-volt discretes and 32 +28-volt discretes shall be provided. Provisions shall be made for two additional cards, each capable of handling either 8 +28-volt discretes or 48 +15-volt discretes. Output capability for 80 discretes shall be provided.

3.6.3.2.3 Analog Inputs

Input capability for 58 analog signals shall be provided with expansion provisions for an additional 16.

3.6.3.2.4 Analog Outputs

Output capability for 12 analog signals shall be provided with expansion provisions for an additional three. Analog outputs shall be produced by digital-to-analog converters with a resolution of 9 bits plus sign (least significant bit is 20 millivolts), and an accuracy of ±0.25 percent of full scale (±10 volts).

3.6.3.2.5 Digital Input

Digital input shall include the following interfaces:

Name	Input Type
LTN-51 Interface	32 bit serial
TACAN Receiver	28 bit serial
F/D Converter	Static Pressure Sensor Audio Frequency
DME	32 bit serial
MODILS (DME)	32 bit serial
MODILS (Elevation and Azimuth)	27 bit parallel
TCG	32 bit parallel
1819B/1819B Interface	18 bit parallel plus control lines

3.6.3.2.6 Digital Output

Two serial digital transmitters shall be provided; bit rate of each shall be 50 kHz.

3.6.3.2.7 Data Acquisition System Interface

A 16-bit parallel interface shall be provided for the transfer of data to the data acquisition system. The contractor shall determine the rates of data output. The data to be output shall be identified in the Data Acquisition Interface Document.

3.6.3.3 Digital Program Loading and Troubleshooting

The digital computation function shall be designed to ease program debugging and troubleshooting by structuring the software to be highly modular via maximum utilization of subroutines.

Software programming aids, which include general utility type routines as well as operational program debugging aids, shall be provided. The routines shall be provided in fixed-point single and double precision.

3.6.4 Aircraft Flight Control Servos

The V/STOLAND aircraft control system shall interface the digital computer data adapter to the aircraft controls for the automatic configurations (Section 3.4) and for CSS mode operation. The pilots shall be aware, through movement of their controls, of V/STOLAND operation to control the aircraft flight path. V/STOLAND operations to augment aircraft stability or to implement CSS modes shall not cause objectionable motion of the research pilot's controls.

The contractor shall provide all parallel trim actuators, hydraulic filters, collective bungee assemblies and switch kits, all LVDT position sensors, the control stick force sensor for pitch and roll, the pedal force sensor and all mounting brackets required to support these items.

The government shall supply all series actuators and solenoid valves.

The contractor shall be responsible for installing all actuators and associated equipment in the aircraft.

3.6.4.1 Servo Interlock Unit (SIU)

The SIU shall contain the servo valve amplifiers, power supplies and interlock circuits for the electrical-to-mechanical interfaces for the controls listed herein and for interfaces as required to existing aircraft actuators.

Power to the servo solenoids shall be provided through the SIU; the solenoids shall receive power only when the SIU receives a "valid" signal from the data adapter and a signal which confirms operation of self-check routines.

3.6.4.2 Pitch Cyclic, Roll Cyclic, Directional, Collective Pitch

Pitch cyclic, roll cyclic, directional and collective pitch shall be driven by electrohydraulic actuators which shall have sufficient power to perform the required aircraft control movements at the required rates. Each actuator shall be supplied with a solenoid-actuated center lock mechanism which converts the actuator to a rigid link to allow rapid engagement and disengagement of servo control forces.

3.6.4.3 Pitch Cyclic Trim, Roll Cyclic Trim, Directional Trim, Collective Pitch Trim

Pitch cyclic trim, roll cyclic trim, directional trim, and collective pitch trim shall be driven by electromechanical actuators which shall have sufficient power to trim the above aircraft controls. Additionally, the actuators shall have an electromagnetic brake to provide manual trim.

3.6.4.4 Collective Bungee Preload Spring

A collective bungee preload spring shall be supplied to allow the collective trim inputs to be mechanically summed with manual inputs such that manual override forces are at acceptable levels. An electrical switch mechanism shall be supplied to sense a breakout of the bungee.

3.6.4.5 Bungee Switch Kit

A bungee switch kit shall be provided for pitch cyclic, roll cyclic and directional bungees to sense bungee breakout.

3.6.4.6 Position Sensors

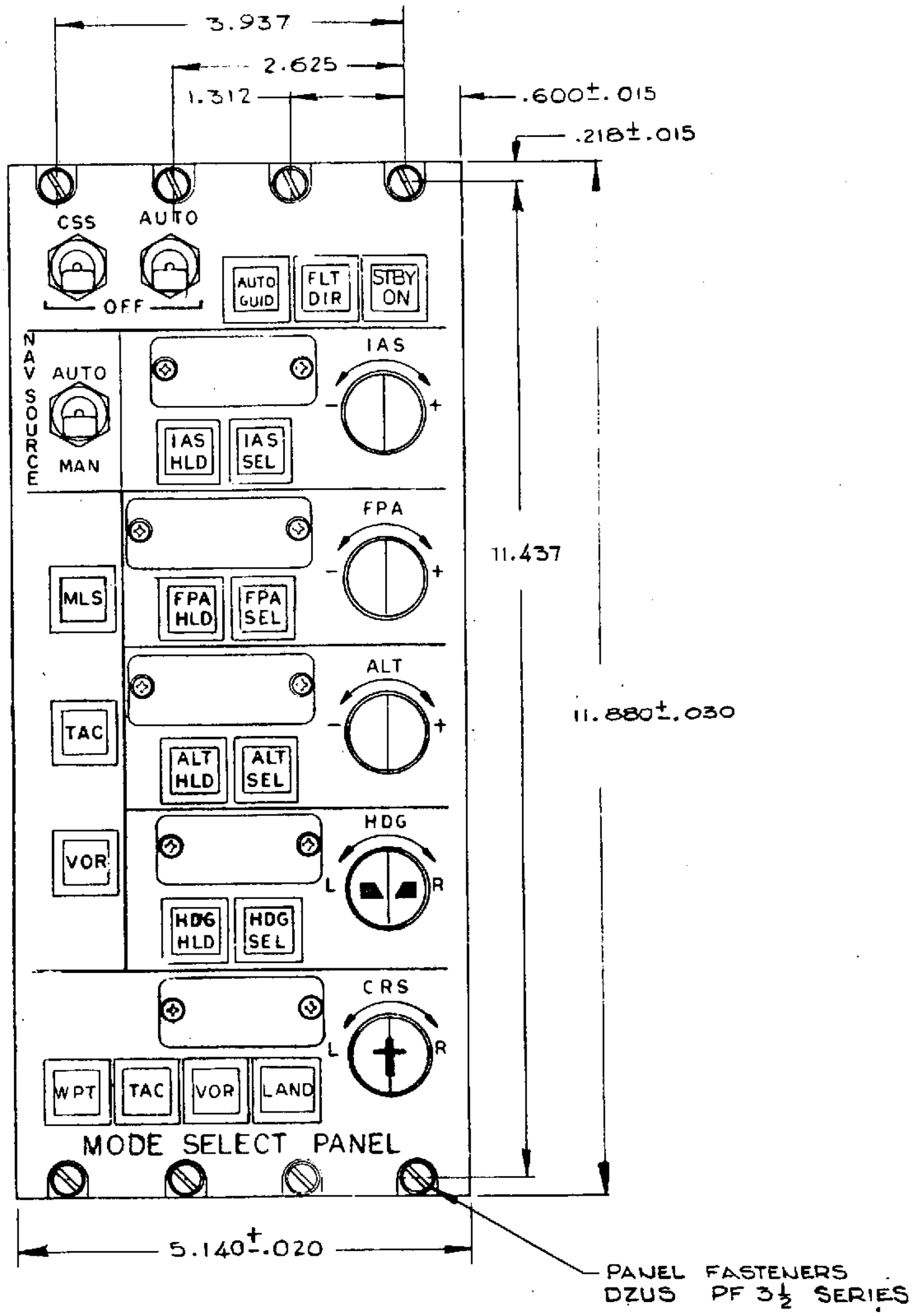
LVDT position sensors shall be provided by the contractor to sense the position of the cyclic and directional trim servo outputs and the research pilot's collective stick position.

3.6.5 Pilot Controls

The contractor shall define the most desirable locations for V/STOLAND controls within convenient reach on the research pilot's (left-hand) side of the aircraft cockpit. Installation and connection of the controls shall be performed by the contractor. Final location of the controls, which may be different from the contractor's recommended location, will be defined in the Aircraft Interface Document (Section 3.9.5). Control configurations and the recommended cockpit layout shall be planned and designed to minimize pilot workload in the manual configurations.

3.6.5.1 Mode Select Panel (MSP)

The MSP shall provide capability for the pilot to select V/STOLAND configuration, navigation data source, flight director and autopilot modes, and mode reference values. The MSP layout shall be as shown in Figure 3.6.5.1. Pushbuttons shall be of the momentary contact



MODE SELECT PANEL
Figure 3.6.5.1

type, shall be lighted, and the backlighted labels shall be easily changed. Button lamps and displays shall have sufficient brightness to have good legibility under ambient light conditions. Button lamps shall be replaceable from the front of the panel. The display lamps shall be replaceable by removal of the front panel.

The V/STOLAND MSP may be physically and electrically replaced by the STOLAND MSP (ref. Specification A-16851), except that the following V/STOLAND functions will be lost:

- Switch legends in many cases will be improper (although push-button caps could be exchanged with V/STOLAND panel);
- Panel engraving for solenoid-held switches will be incorrect;
- Two-color illumination of navigation source pushbuttons will not be available.

3.6.5.1.1 MSP Display

The MSP display shall define the reference values for the flight director and autopilot modes. The display shall consist of segmented incandescent numerals and signs. Ranges of the displays are described in Section 3.6.5.1.2. Indicated Airspeed (IAS) in knots shall be presented in three digits to the nearest knot. Flight Path Angle (FPA) in degrees shall be presented by a "+" or "-" sign and three digits to the nearest 0.5 degree. Altitude (ALT) in feet shall be presented in four digits to the nearest 100 feet (last two digits shall be zeros unless changed by means of the keyboard). Heading (HDG) and Course (CRS) in degrees shall be presented in three digits to the nearest degree. Three NAVAID pushbuttons shall be provided to allow the pilot to select the desired guidance reference.

3.6.5.1.2 Slew Switches

For each of the MSP display windows, a slew switch shall be located as shown in Figure 3.6.5.1. Each switch shall be fitted with a 9/16-inch diameter by approximately 3/4-inch-high splined knob. The pilot shall be able to increase or decrease the mode reference values shown in the MSP windows by turning the knob clockwise for increase and counterclockwise for decrease. As noted below, some of the switches shall select low and high rates of change. The deflection required for high rate shall be ±70 degrees or less. The deflection required for low rate shall be approximately 1/2 that of the high rate, and a detent shall enable the pilot to readily sense the switch position. The switches shall be spring-loaded to return to center (zero rate of change). Torque required to operate the switch shall be 1.6 inch-pound or less. The ranges and rates of operation of the slew switches shall be as described hereafter. Reference values beyond these figures and immediate changes shall be achieved by means of the keyboard.

Function	Range	Low Rate -	Increment	High Rate -	Increment
IAS	000 to 120	002/sec	001	020/sec	010**
FPA	15.0 to -15.0	00.5/sec	00.5†	02.0/sec	01.0†††
ALT	0000 to 9500	200/sec	100††	500/sec	500***
HDG	000 to 359*	002/sec	001	020/sec	010**
CRS	000 to 359*	002/sec	001	020/sec	010**

*The HDG and CRS slews shall continue (start over) when the limits of range are reached.
**Last digit shall go to 0 at actuation.
***Shall be rounded to nearest 500 at actuation.
†Shall be rounded to nearest 0.5 at actuation.
††Shall be rounded to nearest 100 at actuation.
†††Shall be rounded to nearest 1.0 at actuation.

The numbers shall not overshoot or dither when the slew switches are released. The displays shall not flicker during slew.

3.6.5.1.3 MSP Operation

Operation of the MSP shall be described in the V/STOLAND Technical Supplement.

3.6.5.2 Status Panel and Keyboard

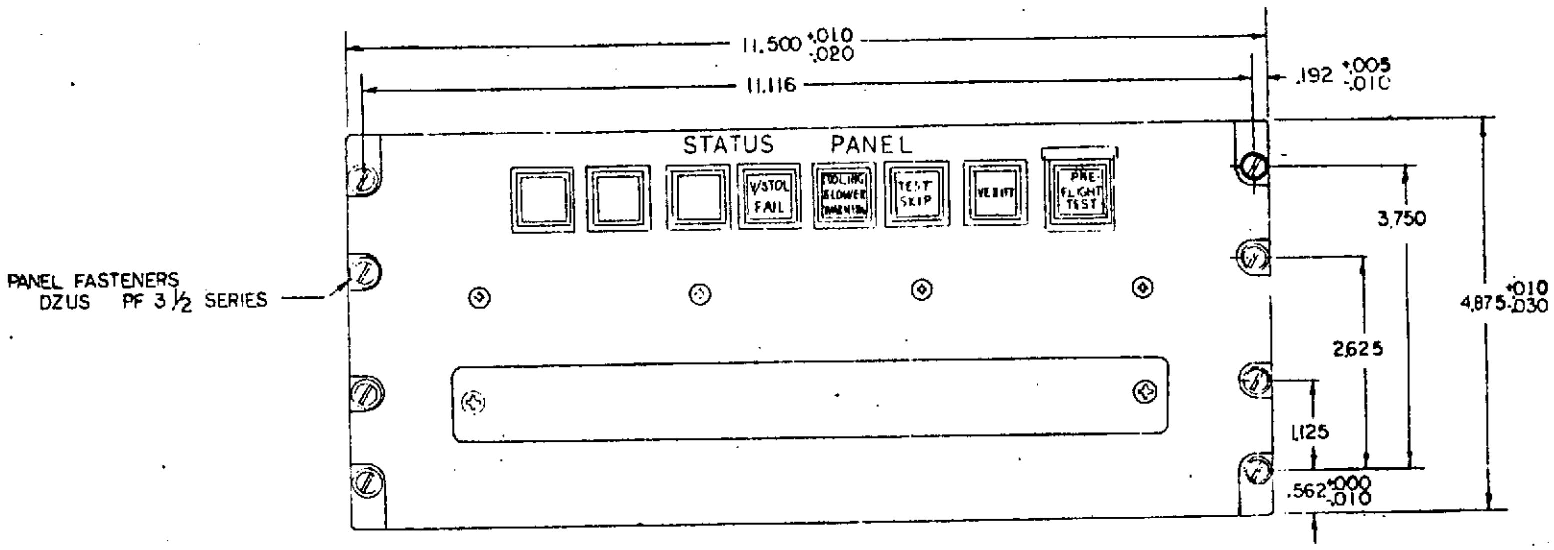
The Status Panel and Keyboard together provide a general purpose interactive interface to the computer.

3.6.5.2.1 Status Panel

The front face of the Status Panel is shown in Figure 3.6.5.2.1. It contains V/STOLAND FAIL, VERIFY/SKIP and Pre-Flight test keys. It also includes a twelve-character alphanumeric 16-segment incandescent status display. The status display shall allow display of of a keyboard command before the command is executed and readout of failures, if they occur. The display lamps shall be replaceable from the front, and shall have sufficient brightness to have good legibility under ambient light conditions.

The V/STOLAND Status Panel shall be physically and electrically interchangeable with its STOLAND counterpart, with the following exceptions

- Different pushbutton switch legends.
- STOLAND Status Panel is not configured to drive amber lights in MFD Control Panel.



STATUS PANEL
Figure 3.6.5.2.1

3.6.5.2.2 Keyboard

The Keyboard (Figure 3.6.5.2.2) shall be identical to the STOLAND Keyboard. Commands and reference settings generated by the keyboard shall be displayed on the Status Display before and after execution. Thirty (30) command keys plus letter/number select, "clear", and "enter" keys shall be provided. All keys shall be of the momentary contact type. Software shall allow the operator to alternate "letter" and "number" selection by depressing the Letter/Number key. The keyboard shall provide the following functions:

a. Select and enter IAS, flight path angle, altitude, course, and heading reference values on MSP display.

b. Select and modify navigation and guidance setting values as appropriate, for instance, barometer setting and decision height.

c. Change aircraft flight control feedback gains.

d. Change CSS mode ratio of pilot force to control parameter.

e. Modify elements of the flight path, initialize time on flight path.

f. Select experimental autopilot and flight director modes as programmed by the Government.

g. Select MFD display contents.

The contractor shall provide mnemonic labels for all parameters that can be called up or changed by the keyboard. The status display shall indicate if an invalid mnemonic is inserted. A typical operation of the keyboard (the example given is the pilot selection of flight path angle autopilot mode) shall be as follows:

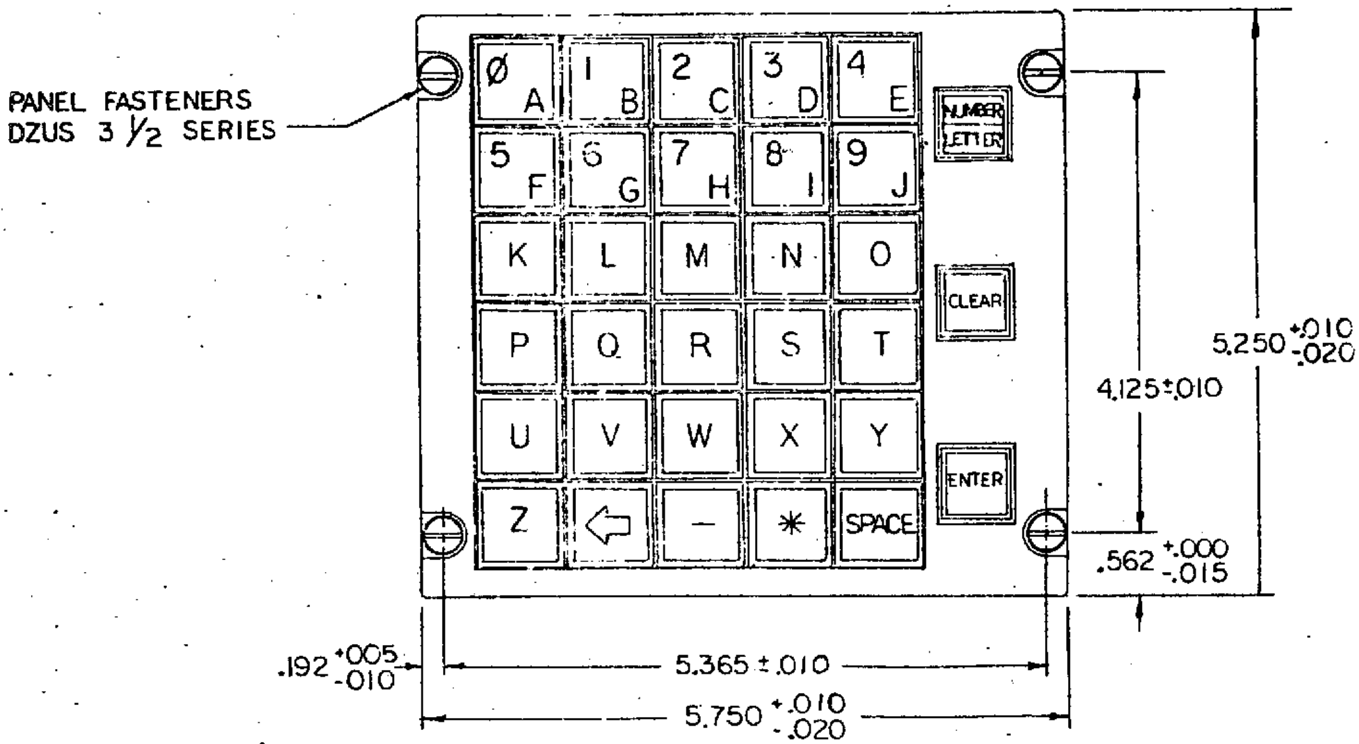
Selects F, P, R, on Keyboard: Status Display displays "FPR = (existing value)", letter/no. key automatically switches to "number"

Select new value on Keyboard: Status Display displays "FPR * (new value)"

Selects "Enter" on Keyboard: MSP will display new value and Status Display will display "FPR - (new value)"

Selection of "FPA SEL" on MSP will control to new value, as described in Section 3.4.2.1.

The keyboard keys shall be illuminated sufficiently to assist the pilot under dim lighting conditions. The Letter/Number button shall be illuminated so that the active legend is brightly lit.



KEYBOARD
Figure 3.6.5.2.2

3.6.5.2.3 V/STOLAND FAIL, Pre-Flight Test and VERIFY/SKIP Keys

A pushbutton labeled "V/STOLAND FAIL," when lighted, shall indicate V/STOLAND failure. Pressing the button shall provide an immediate readout of the failure or failures.

A guarded pushbutton labeled "Preflight Test" shall allow initiation of the preflight test routine (Section 3.5.7.2). A third button shall provide a capability to skip portions of the preflight test and to verify test responses.

Pushbutton lamps shall be replaceable from the front of the panel. Illumination of the pushbuttons shall be provided in two levels - low for off and bright green or red (warnings only) for on.

3.6.5.3 Panel Power Supply

A power supply on the V/STOLAND pallet shall provide power to the status panel, keyboard, MSP, and MFD Control Panel. Provisions for separate remote sensing lines for each voltage and voltage adjustment in response to brightness control shall be included. The panel power supply shall be interchangeable with the STOLAND panel power supply.

3.6.5.4 Control Stick and Pedal Force Sensors

The research pilot's control stick (cyclical pitch control) shall include a four-position trim switch, V/STOLAND cutout switch, microphone switch, crane winch switch, and a control stick force sensor to allow implementation of CSS Modes (Section 3.4.5). The research pilot's pedals shall include a pedal force sensor to implement CSS modes (Section 3.4.5). The sensors shall be insensitive to asymmetric loads applied by the pilot and shall have the characteristics given in Table 3.6.5.4. Closures of the crane winch switch shall be detected by a data adapter discrete input for use by the Basic computer.

TABLE 3.6.5.4

PERFORMANCE CHARACTFRISTICS OF THE STICK AND PEDAL FORCE SENSORS

Characteristic	Performance	
	Control Stick Sensor	Pedal Sensor
Excitation	±15 vdc	±15 vdc
Maximum Output		
Pitch	±11.75 vdc	-
Roll	±9.75 vdc	-
Yaw	-	±10.6 vdc
Linearity	10 percent	10 percent
Null Output	±0.045 vdc	±0.060 vdc
Hysteresis	0.040 vdc	0.040 vdc

TABLE 3.6.5.4 (cont)

PERFORMANCE CHARACTERISTICS OF THE STICK AND PEDAL FORCE SENSORS

Characteristic	Performance	
	Control Stick Sensor	Pedal Sensor
Range		
Pitch	±30 lb	-
Roll	±25 lb	-
Yaw	-	±110 lb
Limit Load		
Pitch	200 lb	-
Roll	100 lb	-
Yaw	-	500 lb

Interface between the control stick, the pedal, and the aircraft shall be described in the Aircraft Interface Document (Section 3.9.5).

3.6.5.5 Brightness Control

The contractor shall provide individual brightness controls for the MSP and Status Displays.

3.6.5.6 Navaid Controllers

Navaid Controllers will be GFE. The contractor shall provide the interconnect wiring to the V/STOLAND pallet.

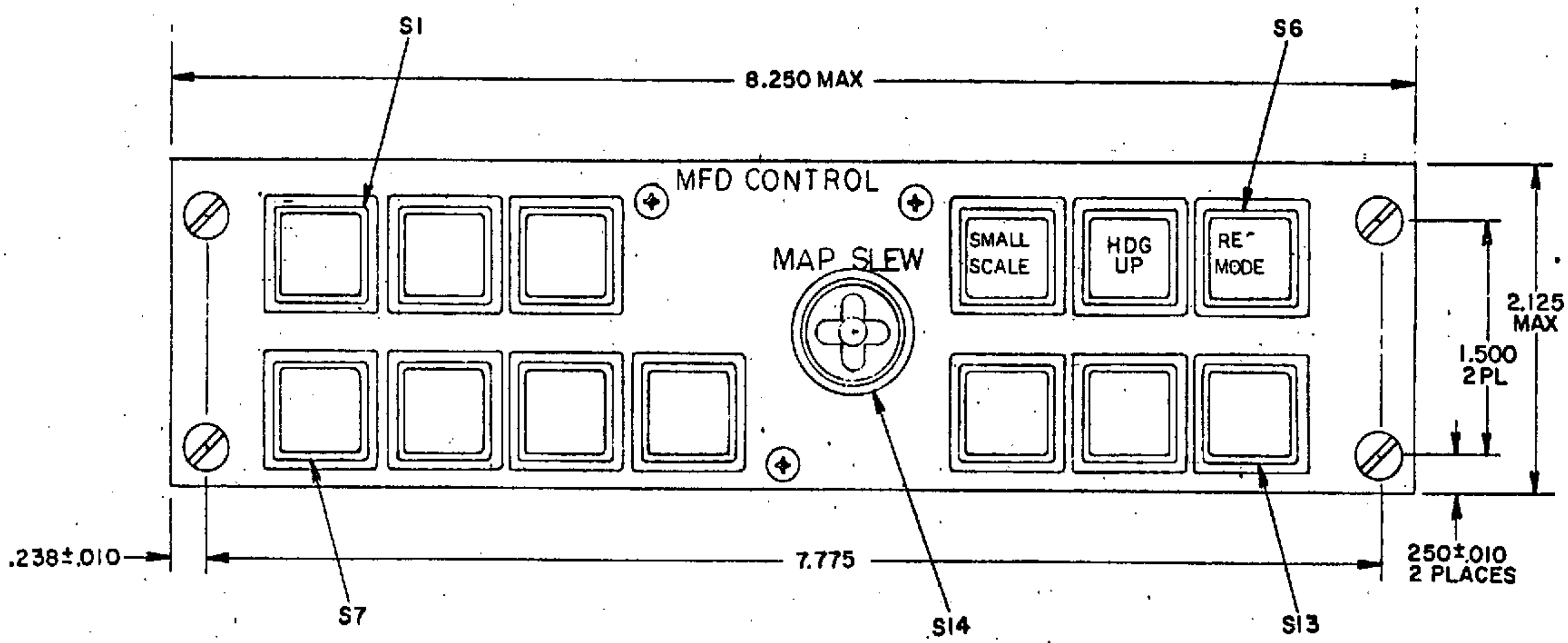
3.6.5.7 Emergency Cutout Switches

The contractor shall provide the emergency cutout switches and associated wire runs and shall be responsible for mounting the cutout switch on the safety pilot's control stick. The emergency cutout switches shall disengage all V/STOLAND servos.

3.6.5.8 Multifunction Display (MFD) Control Panel

The contractor shall provide controls for the MFD on the pilot's instrument panel. These controls shall be located on the MFD Control Panel (Figure 3.6.5.8). The panel contains a four-way map slew switch and thirteen lighted legend pushbutton switches. All switch closures are transmitted to the Basic computer via the Data Adapter. Ten of the pushbuttons shall have the capability of being lighted amber or green under software control. Three of the switches shall have legends as shown; the other ten switches are spares for Research computer use.

This panel is physically interchangeable with the STOLAND MFD Control Panel. The latter panel has different front panel engraving, different pushbutton switch legends, and does not have the capability for amber lighting of the pushbutton switch legends (green only).



MULTIFUNCTION DISPLAY CONTROL PANEL
Figure 3.6.5.8

3.6.6 Pilot Displays

The contractor shall define the most desirable location(s) for V/STOLAND displays on the research pilot's (left-hand) side of the aircraft cockpit for each aircraft. The V/STOLAND displays may replace the existing displays on that side but must leave sufficient room for backup instruments (to be defined in the Aircraft Interface) and for critical aircraft status instruments. Final location of the displays, which may be different from the contractor's recommended location, will be defined in the Aircraft Interface Document (Section 3.9.5).

The V/STOLAND display shall be designed to display the information that the research pilot requires to control the aircraft in the manual, Flight Director and Auto configurations and to monitor the performance and status and manually back up the Auto Guidance configuration. The displays shall allow the research pilot to rapidly assess flight situation information vs command information. One set of display hardware shall be provided for all V/STOLAND configurations. Changes in the display symbols and format necessary for the various configurations shall be accomplished when the pilot changes configurations.

3.6.6.1 Attitude Director Indicator (ADI)

This primary flight instrument presents an integrated display of aircraft pitch and roll attitude, path deviation information and the computed flight director commands necessary to capture and maintain a desired flight path. The Attitude Director Indicator (ADI) shall be the vertical situation display. The contractor shall make all provision possible within the contract to maximize the reliability of the basic attitude information presented on the ADI. Direct connection of the ADI to the attitude reference (VG) shall be provided. V/STOLAND failures, unless generated by the ADI, shall not cause loss of ADI function. The emergency cutout or automatic disconnect shall not shut off the ADI or the attitude sensors.

On the right upper corner of the ADI a decision height indicator shall be red lighted when decision height is reached. On the left upper corner of the ADI a go-around indicator shall be green lighted when go-around mode is initiated.

As programmed in the digital computer, the ADI shall have the capability to display some or all of the following information in combinations as required by the system design, to execute a complete flight plan from engine start to shutdown. Unless noted, each element shall be under software control. The elements shall appear generally as depicted in Figure 3.6.6.1. The elements which are under software control shall be displayed or biased out of view by means of a keyboard request. The HZ-6F ADI unit shall be provided by the contractor.

In addition to the pitch and roll attitude display, three steering cues (cyclic pitch, cyclic roll, collective pitch) shall be controlled by the computer software. Horizontal and vertical deviation indicators shall be controlled by the computer to display deviations from MODILS or ILS beams or computed reference flight path.

HZ-6F ATTITUDE DIRECTOR INDICATOR, PART NO. 2590281

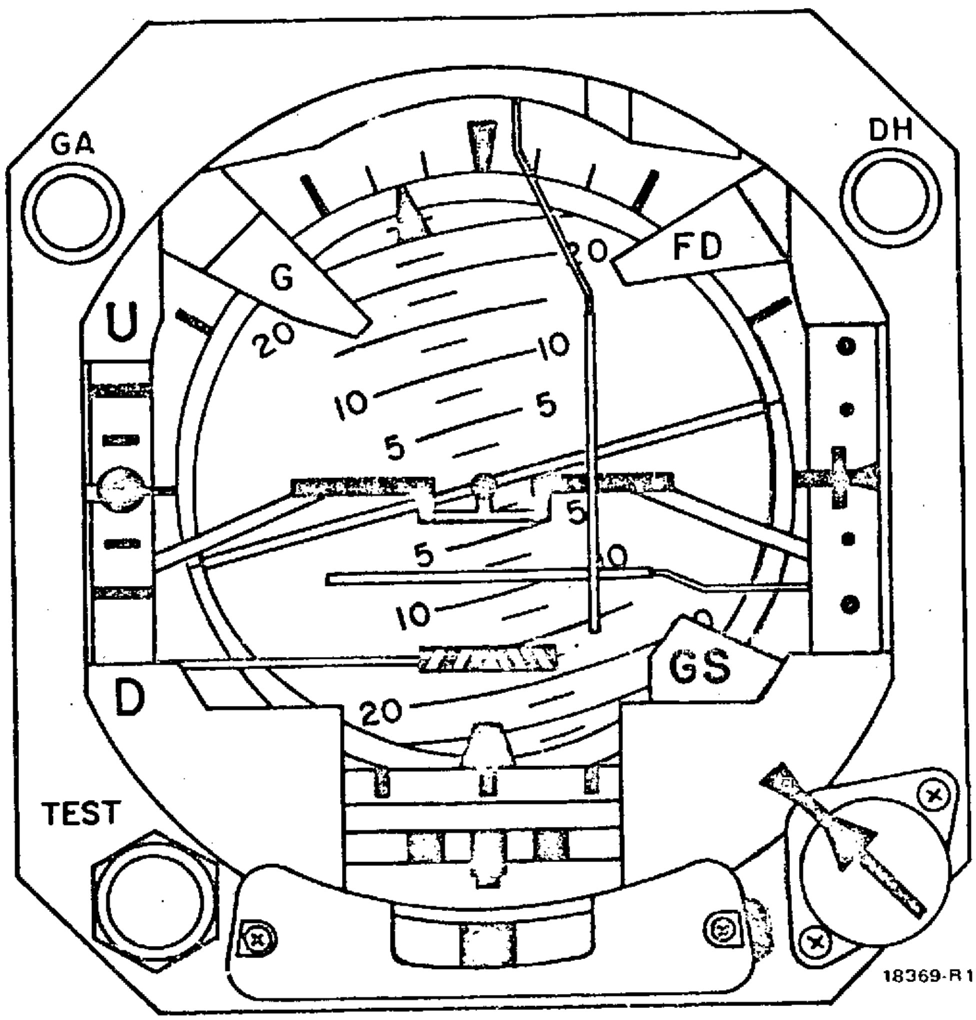


Figure 3.6.6.1

The instrument also includes displays for rate of turn, a rising runway, and an inclinometer.

3.6.6.2 Horizontal Situation Indicator (HSI)

The basic Horizontal Situation Indicator for all configurations shall be an electromechanical instrument of the Sperry RD-202 type, with its associated amplifier and signal conditioner units. Symbols shall be driven from the data adapter where necessary to allow control by the V/STOLAND programs. The HSI shall present the following: aircraft symbol, compass card (heading), heading reference, course reference, to-from indication, course deviation, vertical deviation, dual digital distance windows (to nearest 1/10 nautical mile) and dual bearing indicators. Flags shall appear whenever an indicator does not have valid data. The HSI face layout shall be as depicted in Figure 3.6.6.2, except the actual symbols shall be colored to facilitate pilot recognition. In particular, the tenths digit of the distance windows shall contrast with the tens and unit digits. This unit shall be interchangeable with STOLAND HSI.

Heading and course references shall be changed by means of the MSP HDG and CRS slew switches or by means of the keyboard. Rate of change shall be the same as required for the MSP display (Section 3.6.5.1.2). When the deviation indicators are not receiving data, they shall be centered. When V/STOLAND is operating on a programmed flight path the deviation indicators shall automatically show deviation from that flight path as long as valid data is available.

The glide slope deviation pointer shall display vertical path deviation when MODILS or reference flight path is selected and biased out-of-view in VOR or TACAN. The lateral deviation bar shall display deviation from the radial in VOR or TACAN. The number one distance window and bearing pointer shall operate either on VOR/DME or MODILS, selectable by a switch on the left of the instrument. The number two distance window and bearing pointer shall show distance and bearing to either TACAN or the next waypoint (NWP) of the programmed flight path, as selected by a switch on the right of the instrument. The contractor shall ensure by all means within the contract that the essential heading information is reliably presented regardless of V/STOLAND operating condition.

3.6.6.3 Multifunction Display

A CRT Multifunction Display (MFD) driven by a separate symbol generator shall be provided. From information provided at least once per second by the digital computer, the MFD shall have the capability to display sets of information as called for by the software program. All display symbology shall be stroke-written at a maximum rate of 75,000 inches per second. Refresh of the symbology shall be made 50 times per second. Incremental memory updating, translation, and rotation shall be made 20 times per second. The symbol generator shall contain 256 words of 32 bits in general memory and 64 words of 32 bits in incremental memory. The MFD Display Unit and Symbol Generator shall be interchangeable with their STOLAND counterparts.

RD-202 RADIO DIRECTION INDICATOR

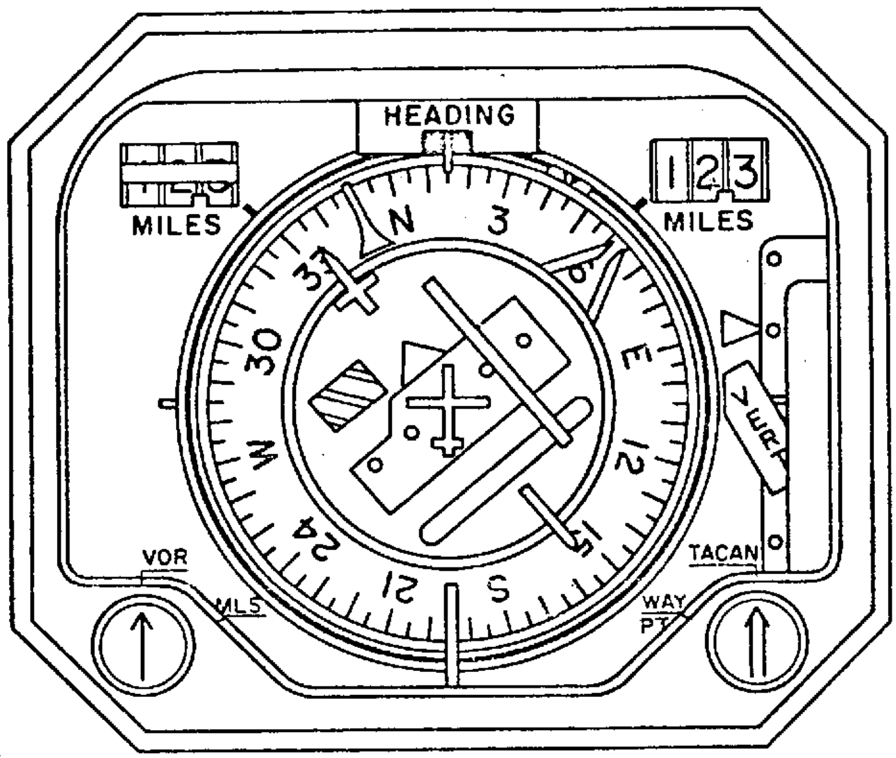


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Figure 3.6.6.2

A test switch shall be provided for displaying a test pattern. A brightness/contrast control shall be provided on the front of the MFD. The display and symbol generator shall include continuous self-test.

A total alphanumeric capability of 26 letters, ten digits and 26 special symbols (including four different vectors) shall be provided by the MFD. Three brightness levels shall be available for each symbol.

The MFD shall automatically display the following data presentations in fixed locations whenever V/STOLAND is operating.

a. Filtered barometric altitude, to nearest foot, in a digital "window" at upper left of the screen. Baro set shall be changed by means of the keyboard, but shall not be displayed on the MFD.

b. Real time in hours, minutes and seconds from the DDAS Time Code Generator (Section 3.6.3.2) in a digital window at upper right of the screen.

Approximate locations of the windows shall be as shown in Figure 3.6.6.3.

The MFD Content Selection, Overall Map, Terminal Area Map, Flight Path Display, North-Up Display, Course-Up Display shall be implemented in accordance with the description given in NASA/ARC Specification A16851 (STOLAND) unless modified by mutual agreement between NASA/ARC and the Contractor. All such modifications shall be describe in the V/STOLAND Technical Supplement. The priorities for retention if some data must be omitted to reduce clutter, shall be defined by the Contractor, but shall be subject to the approval of the Technical Monitor.

The MFD will be used as the primary display in the terminal area and one of the controls shall be committed to call up displays to be programmed by the Government.

3.6.6.4 Failure Warning Display

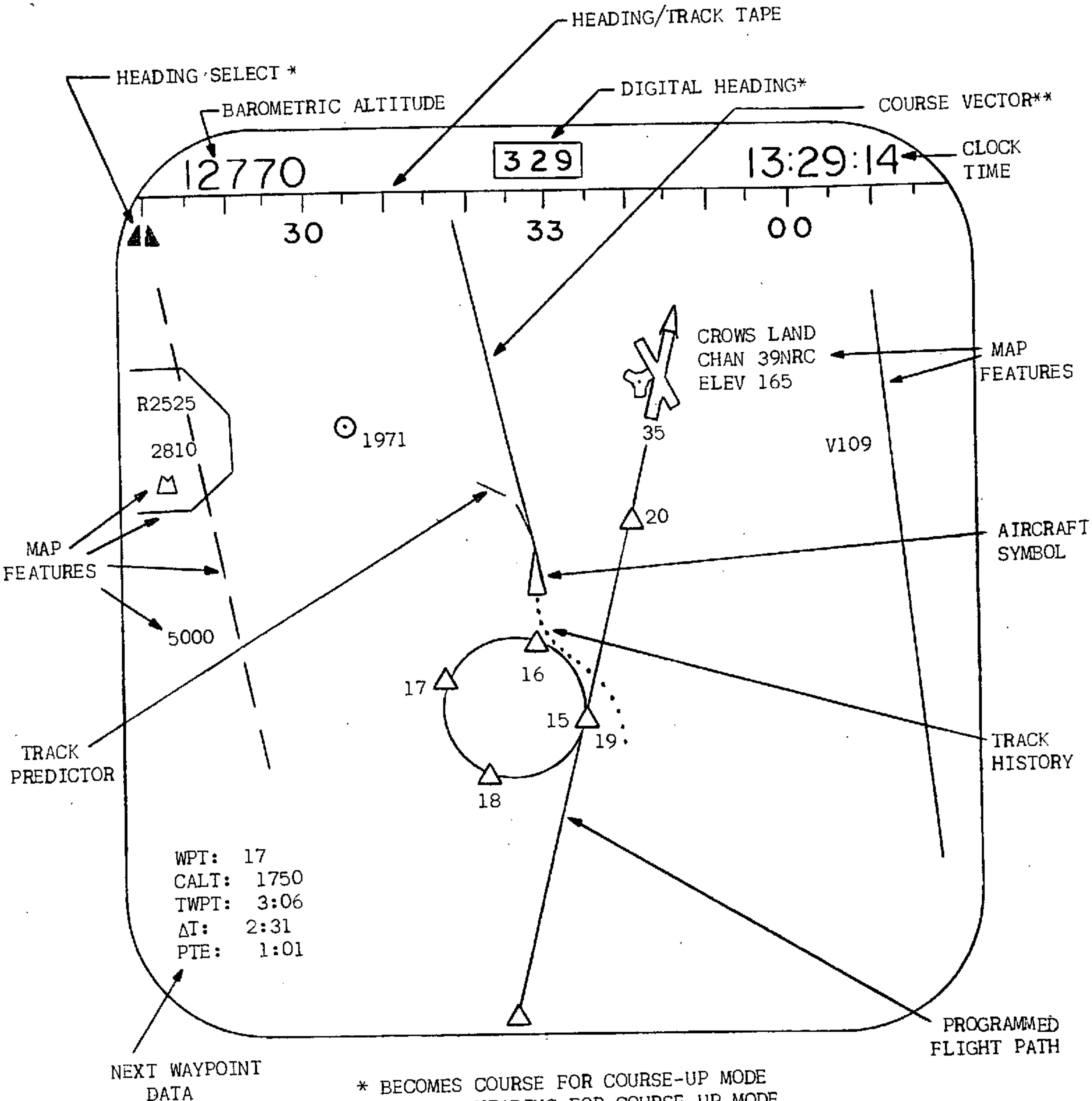
The master V/STOLAND failure warning display shall be provided on the Status Panel in the form of a pushbutton switch which lights with V/STOLAND FAIL and which when depressed, displays on the alphanumeric readout failure or failures detected by the system. The Status Panel shall be visible to both pilots. Other warnings shall be presented on the panel as described in Section 3.6.5.2.

3.6.6.5 Other Information Display

Additional information shall be available on the Status Panel on call by the pilot by means of the keyboard, and shall be identified by the contractor.

3.6.6.6 Warning Indicators

The contractor shall provide two warning lights (one for each pilot) that flash red in the event of V/STOLAND servo disengage (except pilot-initiat disconnects). Other warning indicators are described in Sections 3.6.6.1 and 3.6.5.2.



* BECOMES COURSE FOR COURSE-UP MODE
** BECOMES HEADING FOR COURSE-UP MODE

FIGURE 3.6.6.3 V/STOLAND MFD Showing Moving - Map Display Features in Heading-Up Orientation - Does Not Represent True Scale or Condition

3.6.7 Peripheral Equipment

3.6.7.1 Airborne Hardware Simulator (AHS)

The V/STOLAND airborne hardware simulator shall provide navaid and sensor signals to the V/STOLAND data adapter in the flight format so that the simulator V/STOLAND data adapter and flight V/STOLAND data adapter are identical. The EAI 8400 shall provide navaid and sensor information to the V/STOLAND AHS. The AHS shall also provide for simulation of the servo interface to the data adapter. The AHS will be GFE, but all necessary modifications shall be performed by the contractor. After modification, the AHS will be usable for both STOLAND and V/STOLAND.

3.7 Ground Support Equipment (GSE)

GSE shall include all equipment required for verification of system performance except the peripheral equipment identified in Section 3.6.7. GSE shall include interface harnesses. Preflight testing, with fault isolation to the line-replaceable unit, shall be performed using the airborne digital computer; no GSE shall be required for this test.

3.7.1 Utilization

GSE shall be fully used during the acceptance testing defined by Section 4.5, and exercised through all of its functional features. Test points and connectors shall be designed into the STOLAND to allow the GSE to perform its functions without demating STOLAND connections. Extra plugs, connectors, or cable-bundle "Tees" provided for connection to GSE shall have suitable circuit protection and shall be fitted with captive covers to protect against EMI. The contractor shall provide manuals for the operation and connection of all GSE he provides.

3.7.2 Computer Control Panel

The Contractor shall provide a control unit that interfaces directly with the computer to allow manual control, programming and diagnostic tests in the aircraft (on the ground) or in the simulator. This unit shall allow setting and indicating the contents of major registers, for setting and indicating mode and sequence control, for shop maintenance procedures, and for manual control of the computer.

3.7.3 Automatic Test Equipment (ATE)

The existing STOLAND ATE console at NASA Ames shall be used for complete ground automatic test and fault isolation to the subassembly level for all V/STOLAND flight hardware components. Additional programming and cables shall be provided to test the following V/STOLAND equipment items:

Status Panel
MFD Control Panel
Mode Select Panel
DDAS Instrumentation Unit
Servo Interlock Unit
Data Adapter
Attitude Director Indicator

3.7.4 Peripherals Controller

The peripherals controller shall provide the data and control interfaces between the NASA/ARC furnished peripheral equipment (i.e., paper tape punch, paper tape reader, line printer, KSR-35 teletype and punch and reader) and the computer. It shall contain all control logic to enable parallel data transfers between the computer and the peripherals.

3.8 Government-Furnished Equipment and Facilities

The physical and operational interfaces between the contractor's equipment, software, and GSE and government equipment, software and facilities shall be defined and controlled in the interface documents listed in Section 3.9.

3.8.1 Equipment Furnished At Contractor's Plant

The following equipment will be provided by the Government at the contractor's plant for interface verification as specified by the contract schedule. Data manuals and other information will also be provided for each equipment item. This equipment shall be returned to the government with the flight system or upon request.

GFE Navigation Sensors (Section 3.6.2.3)
Time Code Generator portion of DDAS
Simulator Equipment Rack
Flight Equipment Racks

3.8.2 Nondeliverable Equipment

3.8.2.1 Aircraft

One aircraft will be provided, a UH-1 Helicopter manufactured by Bell Helicopter Company.

3.8.2.2 Ground Facilities

Instrumented range and airport at a location close to NASA/ARC.

Ground-based navigation and guidance aids including VOR/DME, TACAN, MODILS, ILS and MRS.

NASA/ARC simulation of the V/STOLAND Flight Research System.

3.9 Interfaces Between Contractor-Furnished Equipment and Government-Furnished Equipment and Facilities

The interface documents defined herein shall be defined and controlled by agreement between NASA/ARC, representing all Government agencies, and the contractor in the manner required by the contract. For each interface document defined herein, a cover document will be prepared by NASA/ARC to identify the latest versions of the individual documents that describe the interface. The Contractor shall provide all of the Interface Documents and submit them in accordance with the schedule in the Statement of Work.

3.9.1 Software

This document shall provide an overview of the airborne software program in the Basic computer and applicable portions of the Research computer, and shall include a tabulation of core and time usage by function, loading procedures, change procedures, and software control.

3.9.2 Airport and Range Instrumentation

This interface document will be maintained by the contractor to define the airport facility and the range instrumentation to be provided. It will consist of sketches and specifications as appropriate.

3.9.2.1 Content

The information to be controlled will consist of:

Airport location
Airport elevation
Ground-based tracking accuracies versus range and altitude
Detailed map locating features that are to be depicted in the MFD map (Section 3.6.6.3)
Location of navigation and guidance aids in relation to runway touchdown point
Facilities available at airport
Airborne photography accuracy
Time base for measurements

3.9.3 Navigation Aids

The contractor will be responsible for defining this interface. The interface will consist of drawings, specifications, and written descriptions.

3.9.3.1 Content

This interface will control:

Division of responsibilities for interface with GFE Navaids
Navigation aid operation and precision (error models)
Receiver output characteristics including frequencies, coding, amplitudes, rise times, and accuracies
Physical interface including plugs/connector types, pin assignments, mounting
Aircraft attitude limitations and antenna patterns

3.9.4 Data Acquisition

The Data Acquisition Interface document shall consist of drawings, schematics, wiring diagrams, tables and specifications. Both contractor and Government inputs will be required. NASA/ARC will provide necessary information to the contractor for this document as specifically requested in writing.

3.9.4.1 Content

The information to be controlled shall include:

- Locations of sensors
- Range of sensors
- Accuracy of sensors including a calibration curve for each sensor
- Type of sensor and range or set point
- Channel assignments
- Pin assignments
- Plug/connector physical interface
- Recorder channel assignments
- Frequency and tolerance
- Impedance matching requirements
- Data sample rates
- Timing pulse definition
- Data formats
- Data sample rates
- Digital Data Acquisition System description
- Computation requirements and agency responsibilities

3.9.5 Aircraft

An Aircraft Interface Document shall be provided for the UH-1 Helicopter. This document shall consist of drawings, schematics, wiring tables and specifications as appropriate. Both contractor and Government inputs will be required, and NASA/ARC will provide necessary information to the Contractor as specifically requested in writing.

3.9.5.1 Content

The information to be controlled shall include:

- Location of components and flight rack, mounting requirements
- Size of components (non-rack-mounted)
- Wire routings
- Electrical interfaces with aircraft equipment
- Interface connections (wire bundles), type and location
- Mass distributions
- Connector pin assignments
- Servos-aircraft mechanical interface
- V/STOLAND-GFE servos interface
- Aircraft performance
- Aircraft control laws
- Locations of controls and displays
- Maximum forces required to operate V/STOLAND
- Force levels for automatic servo disconnect and for pilot override of servos
- Definition of emergency condition indications
- Power
  - Voltages
  - Current limits
  - Tolerances

Voltage variations versus load
Voltage/current spikes and transients
Power utilization profile
Aircraft maneuvering load limits, unsafe maneuver definition
GFE Magnetic heading sensor characteristics

3.9.6 Laboratory Simulation

The Laboratory Simulation Interface Document shall consist of drawings, schematics, wiring diagrams, tables and specifications as required. Both Contractor and Government inputs shall be required. (See STOLAND MQP Document Section XI.F). NASA/ARC will provide necessary information to the Contractor for this document as specifically requested in writing.

3.9.6.1 Content

The information to be controlled shall include:

Simulator Cockpit
Mounting provisions
Electrical requirements
Interconnect cable lengths
Simulation Computer (EAI 8400)
Aircraft dynamic characteristics
Data formats
Program listing
Interconnect cable lengths
Connector configuration, pin assignments
Sensor simulation characteristics

3.9.6.2 NASA/ARC Simulation

The laboratory simulation will be installed in a UH-1A cab at NASA/ARC and this simulation is defined as the NASA/ARC simulation. For this simulation the Contractor shall define and justify the criteria required to verify and checkout the V/STOLAND hardware, software and flight procedures by simulation. This definition shall include the simulation Math Model. Simulator requirements to be defined specifically shall include:

(1) Simulated hardware and the technique utilized.
(2) NASA/ARC Simulator to be used (EAI 8400)
(3) Frequency range to be simulated including a discussion of rotor dynamics if they are required.
(4) Data necessary for simulation implementation.
(5) Acceptance criteria and accuracies.

3.9.7 Inertial Navigation System (INS)

The INS Interface Document shall consist of drawings schematics, wiring diagrams and specification for the Litton-51 Inertial Navigation System.

Both contractor and Government inputs shall be required. NASA/ARC will provide necessary information to the Contractor for this document as specifically requested in writing.

3.9.7.1 Content

The information to be controlled shall include:

Electrical characteristics
Characteristics of information available from INS
Information request form V/STOLAND
Data adapter information handling provisions.

4.0 PERFORMANCE ASSURANCE

4.1 Reliability

The contractor shall implement a reliability program that will assure meeting the V/STOLAND safety requirements and provide an operable research system. The provisions of NHB 5300.4 (1A) "Reliability Program Provisions for Aeronautical and Space System Contractors" shall be satisfied except for the following sections which shall be deleted:

Section/Subsection	Title
1A201-2e	Reliability Program Plan
1A201-3	Separate Site Plans
1A202	Reliability Program Control
1A203	Reliability Progress Reporting
1A204	Reliability Training
1A305-2	Design Reviews by Suppliers
1A307	Standardization of Design Practices
1A308	Parts, Devices and Materials Program
Chapter 4	Testing and Reliability Evaluation

The contractor's reliability program shall also satisfy the special requirements given hereunder.

4.1.1 Reliability Program Plan

The Reliability Program Plan (RPP) required by Section 1A201 of NHB 5300.4 (1A) shall consist of the RPP prepared and maintained for STOLAND, as modified by V/STOLAND Reliability Program Plan Supplement. The Supplement shall reflect those areas of the V/STOLAND program which differ from STOLAND either because of hardware additions or modifications, or because of procedural considerations. As a minimum, the following program elements will require redefinition and discussion in the Supplement:

a. Design Reviews - discussion of the design reviews shall include the Preliminary, Final, Software and Flight Readiness Reviews, and shall reflect the emphasis to be placed on servo and servo monitor implementation, as well as coverage of review of the software package.

b. Failure Mode and Reliability Analyses - the coverage and the timing of the Failure Mode and Effects Analysis (FMEA) and the Reliability Analyses shall be described in the RPP Supplement, as provided by the contract.

4.1.2 Design Review Program

The contractor is encouraged to use the guidelines contained in NASA document SP 6502 "Elements of Design Review for Space Systems" in the development of his design review program in addition to those of NHB 5300.4 (1A).

4.1.2.1 Hardware Design Review

Design review meetings shall be conducted, as required by the contract, at the component and system levels for flight, simulation and ground equipment (GSE). The contractor shall notify the NASA Technical Representative of the schedule date, time, and location of the Design Review at least ten working days prior to the review. At the time of the notification, the contractor shall provide an agenda and sufficient descriptive information to enable NASA to evaluate the proposed design. The contractor shall prepare and submit to NASA a written report of the review within fifteen working days after the review meeting and shall include a listing of participants, actions to date, and any other pertinent data. The following subjects shall be discussed:

(1) System or component performance
(2) Environmental criteria (including EMI)
(3) Interface definitions (functional and physical)
(4) Acceptance criteria
(5) Top drawings and schematics
(6) Test specifications or procedures
(7) Safety and reliability analyses, including Failure Mode, Effects, and Criticality Analysis
(8) GSE (Ground Support Equipment) and facilities requirements
(9) Design criteria

4.1.2.2 Software Design Review

A Software Design Review shall be conducted, as required by the contract, to demonstrate the effective inplementation of all software modules peculiar to the V/STOLAND system, and their integration with the existing STOLAND software modules which are to be used. For all new or modified software modules, the following items shall be covered at the review:

(1) Modularity of the software elements
(2) Memory and cycle time requirements
(3) Monitoring and self-check features
(4) Mode interlocks and limitations
(5) Ranges of variable parameters
(6) Documentation

4.1.2.3 Flight Readiness Review

A Flight Readiness Review shall be conducted prior to commencing first flight testing. Data required for the Flight Readiness Review shall include a comprehensive summary of all nonconformances that have occurred since the last design review, the significance of each nonconformance to the V/STOLAND performance, and actions taken or in progress to prevent recurrence.

4.1.2.4 Airworthiness and Flight Safety Review

During the program, the contractor shall support reviews requested by the Airworthiness and Flight Safety Review Board (AFSRB) as directed by the NASA Technical Monitor. Up to three such reviews may be required, and they will normally be held separate from other design reviews, at the discretion of the AFSRB. Notification of time, and degree of participation required, shall be made to the contractor such that adequate time is available for necessary preparations.

4.1.3 Nonconformance Reporting and Corrective Action

The contractor's nonconformance reporting and corrective action system shall satisfy the requirements of NHB 5300.4 (1A), Paragraph 1A306, as amended by the requirements of Paragraph 4.1.3 of this specification.

For the purpose of this specification, the term "Nonconformance", as defined in NHB 5300.4 (1A), Appendix C, shall apply.

4.1.3.1 Notification of Major Nonconformance

The contractor shall notify the NASA-Ames Technical Monitor by wire or TWX within one working day of the occurrence of any major nonconformance. A major nonconformance is defined as one which indicates a basic functional design deficiency, exhibits characteristics that necessitate major rework that could have an impact on established schedules, pertains to flight hardware which has been subjected to overstress conditions (either physically or functionally), or creates a critical or catastrophic safety hazard.

Telegraphic notification shall include, as a minimum, the information required by Paragraph 1B801 of NHB 5300.4 (1B) and an indication of probable impact on scheduled events or milestones.

It shall be the responsibility of the contractor to determine whether nonconformances are major.

4.1.3.2 Initial Nonconformance Documentation Submittal

Nonconformance documentation equivalent to that specified in 1B801 of NHB 5300.4 (1B), including the date of nonconformance for all nonconformances of system, subsystems, components, or parts, shall be submitted to the NASA-Ames Technical Monitor within five working days of occurrence for each nonconformance. This nonconformance documentation shall be required for the following nonconformance categories at the serialized LRU level commencing with the system static acceptance test:

(1) Any part replacement, even though the disposition is given as "Rework".

(2) All incidents requiring repair actions.

(3) All rework actions except those for cosmetic purposes only, which do not affect form, fit, function, reliability or safety.

(4) All items resulting in a "Return to Vendor" disposition.

(5) Any nonconformances resulting from out-of-control manufacturing processes, even cosmetic problems, which require an investigation of the process parameters involved.

Reports shall be required for nonconformances, as defined above, to flight hardware, ground support equipment, government furnished equipment, as well as software elements associated with this hardware.

Prior to the system Static Acceptance Test, nonconformance reporting will be accomplished in a manner identical to that obtained for STOLAND (NAS 2-6567).

4.1.3.3 Nonconformance "Close-Out Data Package" Submittal

The contractor shall attempt to close out each NCR within 5 days of occurrence. Copies of the close-out data package shall be provided to the Technical Monitor for review in accordance with the contract.

A nonconformance close-out data package is defined for the purpose of this specification as:

> A completely processed nonconformance report accompanied, where appropriate, by failure analysis reports, test reports and any other supporting documentation necessary to satisfy the requirements of NHB 5300.4 (1A), Paragraph 1A306 and MHB 5300.4 (1B), Paragraphs, 1B801, 1B802, 1B803 and 1B804.

In addition to the minimum data requirements defined above, the nonconformance close-out data package shall include:

(1) The nomenclature, assembly number, and serial number of the highest level of assembly affected, all intermediate levels of assembly affected, and the causal element or lowest level of assembly affected.

(2) Where circuit designators have been assigned for hardware elements, they shall be included in the identification details, where nonconformances occur in next assemblies.

(3) For each level of assembly and hardware element involved in a nonconformance, where the disposition is "return to vendor", the actual manufacturer's name shall be given.

(4) Identification, by assembly number and serial numbers, of all items for which remedial action is to be accomplished and objective evidence of accomplishment.

(5) Test results supported, as appropriate, with interpretation and analysis, supporting the validity of a design change impacting on functional characteristics.

(6) When the nonconformance occurs during a contractually-required test, the test document number, the paragraph or section involved, the correct response, and the nonconforming response.

4.1.3.4 Failure Analysis and Corrective Action

The contractor shall employ a strictly-controlled closed-loop system for the reporting, analysis, correction and data feedback of all failures and malfunctions that occur throughout the fabrication, handling, test, checkout and operation of the deliverable airborne equipment, software and GSE. This system shall emphasize reporting and analysis of nonconformances that occur, so that timely and appropriate evaluation, remedial and preventive action can be accomplished by cognizant design, fabrication, quality and/or field personnel.

4.1.3.5 Cumulative Status Reporting of Nonconformances

The contractor shall prepare and submit to the Technical Monitor a cumulative listing of all nonconformances written against the contract. Reports shall be submitted with the periodic Reliability Program progress reports. Reports shall contain, as a minimum, the following information:

(1) Nonconformance Report document number
(2) Date of nonconformance
(3) Criticality classification
(4) Identification of highest level of assembly affected
(5) Contractor closure status
(6) For items still open, a brief description of the plans pending or activity in process to effect closure, and the expected closure date.

4.1.4 Parts and Materials Program

4.1.4.1 Selection Criteria

a. Standard Production Items - under the following conditions, the data for an item may be submitted for NASA approval without the normally required detailed parts and materials list:

(1) If the item proposed for use is a standard production item of the manufacturer, without modification, and has supporting qualification or usage data.

(2) If the item proposed for use has been previously approved for use on a similar NASA project.

b. Non-standard Production Items - Parts and materials for new components and system elements shall be selected to ensure maximum reliability within program constraints. The parts shall be selected from Section 3 or Section 4 of AHB 5328-1, "Preferred Parts and Materials List" or shall be the commercial equivalent to those listed therein. The materials shall be selected from Section 5 of AHB 5328-1.

c. Acceptability - Parts selection is subject to NASA/ARC Technical Monitor review (i.e., parts selections may be disapproved) as provided for in the contract and in Section 4.1.4.2.

4.1.4.2 Parts List Submittal

Parts and materials selected in accordance with Section 4.1.4.1 shall be submitted, ahead of planned use, on NASA Form ARC 23. For parts and devices which the contractor selects using criteria other than those given in Section 4.1.4.1, information shall be submitted on a NASA Form, ARC 9, but shall also include a description of the planned use and the basis for selection. On Form ARC 9, the "Technical Representative" is the same as the Technical Monitor.

4.1.4.3 Parts/Materials Handling

The contractor shall specify minimum requirements for control of stocking and installation procedures for parts, devices, and materials. These controls shall be designed to prevent use in the system of parts, devices, or materials which may be in questionable condition. They shall also be designed to prevent degradation of parts, devices, and materials due to environments or faulty manufacturing or assembly techniques.

4.1.4.4 Part/Material Problem Review

The contractor shall evaluate the significance of the problem items identified by ALERT reports (NASA Form 863 or GIDEP Form 20) to the equipment under contract and respond to Ames on the PER 060 "ALERT Evaluation Report" for each ALERT received from NASA-Ames. When the contractor encounters a part or material problem which may be of general concern, an ALERT report shall be prepared and forwarded promptly to the Ames ALERT Coordinator. Contractors participating in GIDEP shall process ALERT reports in accordance with established GIDEP procedures.

4.1.5 Other Provisions

4.1.5.1 Reliability Program Documents

The documents referred to in Section 1A104 of NHB 5300.4 (1A) shall be limited to only those called for in the contract. The document classifications shall be in accordance with the contract requirements.

4.1.5.2 Design Specifications

The requirements of Section 1A301 of NHB 5300.4 (1A) shall apply to all components and to the subsystem and system level except that interface specifications are controlled as part of the interface documents (Section 3.9). Control of interfaces and configuration shall be in accordance with the contract.

4.1.6 Supplier Reliability Program

The provisions of Section 1A201-2d and 1A205 of NHB 5300.4 (1A) shall only be applied to those suppliers who have engineering design responsibility for V/STOLAND equipment (not ground support equipment). Design review requirements for suppliers may be met during regular design reviews to avoid duplication.

4.1.7 Failure Mode and Reliability Analysis

4.1.7.1 Failure Mode and Effects Analysis

As an integral part of the engineering design effort, the contractor shall determine possible modes of failure at the LRU output level and shall determine which of these can result in a critical failure at the system output interfaces. The primary objective shall be to identify critical failure areas, to enable removal of susceptibility to such failures or their effects and to minimize the risk of mission loss and maximize crew safety. Where critical system failure modes may occur, an analysis of the LRU(s) responsible shall be made to determine part and component malfunctions leading to the failure mode involved. Where possible, design modifications shall be made to eliminate or substantially reduce the probability of these malfunctions. The results of such analyses shall be provided to NASA/ARC for review, according to contractual schedule.

For critical failure modes which cannot readily be eliminated during the design phase, hardware and/or software monitors shall be implemented to detect these failures, provide crew warning, and disengage V/STOLAND where necessary. The contractor shall demonstrate, by time of final design review, through simulation and analysis, the effects of such failures on the aircraft and the efficacy of the failure monitors.

4.1.7.2 Reliability Prediction and Failure Criticality Analysis

In conjunction with the FMEA, a reliability prediction of each component shall be conducted, and an estimated system MTBF established. Utilizing the reliability prediction, system failure modes having critical failure effects will be reviewed and the estimated probability of each established. The contractor shall recommend corrective action, through redesign or redundancy measures, to meet reliability goals commensurate with an operational V/STOLAND system. The final report on these analyses shall be included in the Final Design Review package.

4.1.7.3 Critical Failure Effects

A critical failure effect is one which results in unsafe aircraft motion...that is, one which results in overstress on structural elements, in the aircraft going out of control, or which requires immediate emergency recovery procedures by the crew. The fact that recovery is possible, or that the failure is displayed to the pilot by means of a warning light or other indicator, shall not change the criticality ranking. Only if automatic recovery is achievable with no pilot action or if there is complete assurance that the pilot has time to reconfigure and no unsafe motion occurs shall the criticality be lessened.

In considering potential failure effects, worst-case flight conditions shall be assumed.

4.1.8 Reliability Reporting

Reliability Program progress shall be reported periodically as a part of contractually required status reports.

4.2 Quality Assurance

The contractor shall implement and maintain a Quality Assurance Program commensurate with the provision of potentially flight-critical aircraft equipment. As a minimum the contractor's Quality Assurance program shall meet the provisions of NHB 5300.4 (1B) "Quality Program Provisions for Aeronautical and Space System Contractors", except for the following sections which may be deleted:

Section/Subsection	Title
1B202-2	Certification of Personnel
1B202-3	Recertification of Personnel
1B202-4	Records
1B204-3 and -4	Quality Status Reporting
1B205	Quality Program Audits
1B206-3	Site Program Plans
1B403	Identification Control
1B404	Identification List
1B405	Retrieval of Records
1B502-1b and -2	Procurement Documents - Contents
1B507	Supplier Rating System
1B508	Post-Award Survey of Supplier Operation
1B604	Workmanship Standards
1B702	Test Specifications - These provisions may be included in the test procedures
1B705-2	Qualification Test Articles
1B705-3	Requalification Testing
1B705-4	Qualification Based on Similarity
1B705-7g	Operating Time Records

Section/Subsection	Title
1B903	Article or Material Measurement Processes
1B904	Calibration Measurement Processes
1B1100, 1B1101, and 1B1102-1	Handling, Storage, Preservation, Marking, Labelling, Packaging, Packing and Shipping
1B1201	Statistical Planning and Analysis

In addition, the contractor shall comply with the following requirements:

4.2.1 Equipment Records

The equipment records required by Paragraph 1B706-2 of NHB 5300.4 (1B) shall begin with the initial test of each component and subsystem. The records shall be consolidated when the components and subsystems are installed in the aircraft and shall be maintained through the completion of the contract.

4.2.2 Delivery Data Package

The documentation package required by Paragraph 1B1102-2 of NHB 5300.4 (1B) shall consist of the records (Reference 1B706-2) for V/STOLAND equipment and calibration data and maintenance requirements for V/STOLAND, for the flight instrumentation, and for GSE.

4.2.3 Installation Inspection

Whenever installation of articles or materials cannot be adequately inspected upon completion of the operation, the contractor's inspection personnel shall exercise sufficient surveillance to assure the installation is made in accordance with the specifications or drawings.

4.2.4 Quality Status Reporting

The Quality Status Report (Section 1B204) shall be coordinated with the Configuration and Interface Control Program required by the contract.

4.2.5 Change Control

The contractor's change control system (Section 1B302) shall be coordinated with the Configuration and Interface Control program required by the contract.

4.2.6 Government Quality Representative

Government quality representative actions will be provided at the component (LRU) level and above only. Inspections of specific items below this level may be performed by the government when directed by the NASA Technical Monitor. Such inspections will be coordinated with the contractor to assure compatibility with his schedule. The contractor is required to make available, at the component (LRU) and system level, prior to acceptance by the Government, documents and records indicating the contractor's completion of all previous manufacturing and test steps. These documents shall contain a notation (acceptance stamp or signature) by the contractor's Quality Control Department signifying acceptance and completion of each work step, operation, inspection, test and calibration as required by Inspection Control Charts. The above shall in no way relieve the contractor from his responsibility to provide supplies in full conformance to the requirements of the contract, work statement, MQP, test specifications and engineering documentation at all levels of performance.

4.2.7 Procurement Documents

The provisions of Section 1B502 of NHB 5300.4 (1B) shall apply to articles listed on the contractor's "Buy" list and to procurements of specially-designed parts or specially-fabricated circuit boards. Purchase orders for standard off-the-shelf piece parts do not require quality assurance review. Such parts are required to meet the criteria of Section 4.1.4, however.

4.3 Safety

4.3.1 General

The design and fabrication of equipment shall provide features for the safety of personnel during the installation, operation, maintenance, and repair, or the interchanging of a complete equipment or any portion thereof. Guidelines are presented in MIL-STD-882.

4.3.2 Electrical

The design shall incorporate methods to protect personnel from accidental contact with voltages in excess of 30 volts (rms or dc) while operating a complete equipment. Suitable protective devices (e.g., interlocks, barriers, enclosures, signs, grounding rods) shall be incorporated to protect personnel from accidental contact with voltages in access of 70 volts (rms or dc) while maintaining equipment. Equipment employing potential in excess of 1,000 volts shall be provided with test points so that all high voltages can be measured at relatively low potential. The main power switch located on the equipment (clearly labeled as such) shall cut off all power to the complete equipment. An indicator lamp shall be provided to indicate "power-on", except for battery operated equipment. Neither side of the supply voltage shall be directly connected to the chassis. Connector shall be selected so that it will be impossible to insert the wrong plug in a receptacle or mating unit. Plugs and receptacles shall be suitably coded or marked to clearly indicate the mating connections.

a. Grounding - The path to ground from the equipment shall be continuous and permanent and have ample current carrying capacity to conduct safely any currents that may be imposed on it. The ground connection to the chassis shall be mechanically secure and corrosion-resistant. Plugs and convenience outlets shall have provisions for automatically grounding the frame or case of external equipment or tools when the plug is mated with the receptacle. The design and construction of the equipment shall ensure that all external parts, surfaces, and shields, exclusive of antenna and transmission line terminals, are at ground potential at all times. Any external or interconnecting cable, where a ground is part of the circuit, shall carry a ground wire in the cable terminated at both ends in the same manner as the ground connection.

4.3.3 Mechanical

Protection shall be provided to prevent personnel from contacting mechanical parts such as gears, fans, and belts when the equipment is complete and operating. Sharp projections on cabinets, door, or similar parts shall be avoided. Equipment design shall include provisions to prevent accidental pulling out of drawers or rack-mounted components. Power switches shall be located so that accidental contact by personnel will not place the equipment in operation. The design shall provide means to prevent the inadvertent reversing or mismating of fittings, couplings, hydraulic or pneumatic lines. When prevention by design considerations is not feasible, coding or marking shall be employed.

4.3.4 Fire Hazard

All items of equipment which in normal operation or failure might provide an ignition source shall be protected as follows:

4.3.4.1 Items which arc or are spark producing during normal or failure conditions shall:

a. Be explosion-proof

b. Be designed to limit surface temperature to below 450°F during normal operation, or during a failure condition.

c. Electrical wiring shall be designed with frequent support, including protective conduits if necessary to prevent chafing of wires. Enough slack shall be left in wires and wire bundles to take into account airframe flexibility. Wire insulation shall be abrasion-resistant.

d. If exposed terminals must be used, the cables shall be supported near the terminal in such a way that loosening of the attaching device due to operation or vibration or by personnel contact is prevented.

e. DC systems which are exposed to wet environments should not be energized longer than necessary.

f. All electrical components shall be positively bonded to ensure adequate grounding of all current paths.

4.3.5 Structural

Mounting screws, bolts, rivets and other fastening devices, and structural members of racks, mounting brackets, etc. shall be of sufficient strength to preclude failure under the maximum acceleration expected in the aircraft, under all normal and emergency conditions and to withstand such incidental abuse as can be expected under all service conditions. The installation hardware and structural members shall withstand static loads of 9g in the longitudinal axis forward, 1.5g in the longitudinal axis aft, 2g in the positive Z axis, 7g in the negative Z axis and 2g in the lateral axis. Stress analysis verifying structure strengths, shall be required to support compliance with this paragraph.

4.4 Workmanship

4.4.1 General

Articles shall be constructed in a thoroughly workmanlike manner. Particular attention shall be given to neatness and thoroughness of soldering, welding, brasing, plating, finishes, riveting, machine assemblies, screw assemblies, wiring and cabling, freedom of parts from burrs and sharp edges, or any defect that could result in unsatisfactory performance.

4.4.2 Soldering

The solder joint shall have a smooth surface, no porosity, a good fillet and adherence to both parts, and even distribution of solder tapering to a feathered edge away from the joint. Flux residue shall be removed.

4.4.3 Welding and Brazing

Welded and brazed joints shall be free of harmful defects such as cracks, porosity, undercuts, voids, burn-through, and gaps. Fillets shall be uniform and smooth. There shall be no excessive angular or thickness misalignment, warpage, or dimensional change due to heat from the welding or brazing operations. There shall be no damage to adjacent parts resulting from the welding or brazing operation.

4.4.4 Plating and Finishes

All plating and finishes shall be free from scratches, flaking, peeling or other defects.

4.4.5 Riveting

Rivets shall be secure and satisfactorily headed with the rivet heads tightly seated against their bearing surface.

4.4.6 Machine Assemblies

Gear assemblies shall be properly aligned and meshed and shall be operable without interference, tight spots, loose spots, excessive backlash, or other irregularities that could cause unsatisfactory performance. Bearing assemblies shall be free of rust, discoloration, and imperfections of ground, honed, or lapped surfaces. Particular attention shall be given to contacting surfaces which shall be free of tool marks, gouge marks, nicks or other surface-type defects. There shall be no detrimental interference binding, or galling.

4.4.7 Screw Assemblies

Screws, nuts, bolts, etc, shall conform to NAS or MS specifications, and shall show no evidence of cross threading, detrimental or hazardous burrs, or mutilation. All screw-type fasteners shall be tight (i.e., no relative movement possible between the attached parts). All screw assemblies shall be made vibration resistant, utilizing lockwashers, safety wire, self-locking nuts, or cotter pins. The length of screws and bolts shall be determined by using the next standard longer size which leaves a minimum of 1-1/2 threads above the surface of the nut.

4.4.8 Wiring and Cabling

There shall be no evidence of burns, abrading, or pinch marks in the insulation that could cause short circuits or leakage. The clearance between wires or cables and heat generating devices shall be such as to avoid deterioration of the wires or cables from the heat dissipated by those devices. Wires and cables shall be positioned to avoid sharp bends, rough or irregular surfaces, and sharp edges. Wiring shall be neat in appearance. Cabling and harnesses shall be properly supported. Lacing shall be applied firmly, yet not with excessive pressure which could cause insulation damage, and shall be neat in appearance. Shielding on wires and cables shall be secured against fraying and positioned in a manner which will prevent contacting or shorting exposed current-carrying parts.

4.5 Testing

4.5.1 Environments

The V/STOLAND equipment shall be capable of withstanding the following environments during storage, shipping and flight:

4.5.1.1 Temperature

Operating, -15°C to +55°C
Nonoperating, -50°C to +71°C

4.5.1.2 Altitude

Operating pressures corresponding to altitudes of -100 meters to +4,572 meters referenced to sea level. Refer to US Standard Atmosphere, 1966.

4.5.1.3 Humidity

Operating and nonoperating, 15 to 95 percent relative humidity.

4.5.1.4 Vibration

Sinusoidal per MIL-STD-810B, Method 514, Table 514.1-III for equipment category (c), "Helicopters". Vibration levels shall be per Figure 514.1-3, curve B.

4.5.1.5 Electromagnetic Interference

As defined in MIL-STD-461A for class ID equipment.

4.5.2 Test Plan

The test program, including all tests required by Sections 4.5.3 and 4.5.4, shall be described in the contractor's Test Plan. The plan shall be time-phased, and shall identify, by specification section numbers, in which test(s) each performance and design requirement of this specification will be demonstrated. A brief description of the test method shall be provided in the Test Plan.

4.5.3 Development Tests

Development tests shall be performed on selected components and on the integrated V/STOLAND to verify the feasibility of the design approach and to provide confidence that the STOLAND will meet the specification requirements. Breadboard and off-the-shelf components and wiring may be used, therefore not all of the specification requirements need be demonstrated. Failures during development tests may be dispositioned by engineering action only, except for failures to flight-designated elements.

4.5.4 Acceptance Tests

Acceptance tests shall be performed to verify that the components and system meet the performance and environmental requirements. System acceptance tests shall be conducted both prior to and after installation in the aircraft. Standard performance tests shall be defined and used to test each component and the integrated V/STOLAND with the peripheral equipment. For V/STOLAND, the real time portions of the test shall be sequenced to match the programmed flight path in the basic computer (Section 3.3.3.2).

4.5.4.1 Components and Parts

Each flight and spare component (line-replaceable unit), including peripheral equipment and ground support equipment shall be subjected to a performance test when its configuration has been brought to final configuration for that unit. In addition, environmental tests shall be performed on each deliverable unit of the following components:

- 1819A Computer
- Data Adapter
- Panel Power Supply
- Servo Interlock Unit
- MFD Display Unit
- MFD Symbol Generator
- Mode Select Panel
- Status Panel
- MFD Control Panel
- DDAS Instrumentation Unit
- HSI Signal Conditioning Unit
- Rate Gyro Assembly
- Accelerometer Assembly
- Static Pressure Sensor
- Control Stick Force Sensor
- Pedal Force Sensor
- Keyboard

The environmental tests shall consist of a temperature test followed by a vibration test. A full functional test need not be conducted during environmental exposure, but shall be conducted pre- and post-test. The tests shall be conducted with power on for electrically-powered components. The temperature test shall consist of one cycle as follows:

> Increase temperature in chamber to +55°C within 1/2 hour. After component temperature has stabilized at +55°C, or after 4 hours reduce temperature in chamber to -15°C within 1 hour. After component temperature has stabilized at -15°C, or after 4 hours raise chamber temperature to room ambient within 1/2 hour. Maximum component exposure to +55°C or to -15°C shall not exceed 4 hours.
>
> The vibration shall consist of a 15-minute (minimum) linear sweep from 5 Hz to 500 Hz at ±2g peak-to-peak (curve B of Figure 514.1-3 of MIL-STD-810B) along each orthogonal axis of the component.

Flight equipment racks shall not be vibration-tested, but the contractor shall assure that components mounted on the racks shall not be subjected to vibration levels in excess of the design levels. Operating equipment normally mounted as part of the rack, such as the cooling blower, shall be subjected to component operation tests and shall be verified as capable of operating under flight environment by test or by comparison to tested units (similarity).

4.5.4.2 Integrated V/STOLAND

Following component acceptance tests, the components shall be assembled into the integrated system using test cables which simulate the aircraft wiring harnesses. Static and dynamic tests shall be performedon each system. Static tests are defined as the application of a set of specific inputs by means of Ground Support Equipment (GSE) and other test equipment and the measurement of the corresponding response.

The static tests are to be end-to-end tests which exercise the system over its entire range. Safety features and system self-check routines (Section 3.5.7) shall be verified. Dynamic tests are defined as end-to-end tests of the complete system using the airborne software in a simulation environment; they shall be performed at ARC. These tests shall serve to verify software and shall demonstrate operation of the manual configurations aided by CSS modes. After arrival at NASA/ARC, dynamic acceptance tests of each system shall be performed in the ARC Simulator, and the system functional capability and integrated system performance shall be verified. The government shall provide the pilots for acceptance testing simulations. All software defined in Section 3.5 and all support software shall be used and validated during test in the NASA/ARC simulator.

Acceptance tests shall include operations over a complete test flight path (Section 3.3.3.2) and operation in each of the flight configurations. Switching in and out of standby and operation of the emergency cutout features shall be demonstrated.

4.5.4.3 Installation and Compatibility

This test shall consist of tests to be defined by the contractor to verify compatibility and correct operation of each system with the system installed in the aircraft and with other aircraft systems operating. Some software routines, including self-check routines (Section 3.5.7) shall be employed in this test.

4.5.4.4 Preflight

Verification of V/STOLAND performance shall be required in the aircraft prior to flight test. This test shall include part or all of the installation tests and shall use the preflight system check routine (Section 3.5.7.2). Supporting equipment shall be limited to that which will normally be used to verify system performance in the aircraft, except for troubleshooting.

4.5.4.5 Flight

This test shall consist of the verification of system operation in flight. Upon completion of preflight acceptance testing (Section 4.5.4.4), the V/STOLAND shall be operated while the aircraft is airborne to perform a simple verification routine which may include a sample problem. The control outputs shall have the correct response to the input data, but guidance accuracies need not be demonstrated. The purpose of the test is to prove operational compatibility with the aircraft.

4.5.5 Qualification

No qualification tests are required for the V/STOLAND or its components.

4.5.6 Airworthiness and Flight Safety

All hardware that interfaces with the aircraft and all modifications that are made to the aircraft shall conform to acceptable techniques and practices as described in the documents of Section 2.0. The design of all such hardware and aircraft modifications will be reviewed by NASA for airworthiness and flight safety, and periodic inspections by NASA/ARC inspectors will be made during the fabrication process. The sections listed below describe particularly significant problem areas.

4.5.6.1 Materials

Only materials listed in MIL Handbook 5B or 694A shall be used for flight hardware interfacing with the aircraft. The manufacturing processes utilized shall be in accordance with the guidelines described in the documents of Section 2.1.

4.5.6.2 Fasteners

Only certified MS or NAS fasteners shall be used. These fasteners shall be utilized in accordance with guidelines as described in the documents of Section 2.1.

4.5.6.3 Limit Loads

All structures mounted in the aircraft must satisfy the requirements of reference 1 of Section 2.0. The Contractor shall verify by static test or analysis that the applicable hardware items do satisfy the prescribed limit loads with a margin of safety greater than zero.

5.0 HANDLING, SHIPPING AND STORAGE

5.1 Handling and Shipping Equipment

The V/STOLAND handling and shipping equipment must be designed to protect the equipment from the rigors of handling, shipping, and storage under expected environmental conditions (Section 4.5.1). GFE shall be included if it cannot be shipped in its original containers due to integration into STOLAND.

5.1.1 Shock Mounting

The contractor shall design durable reusable transporting and shipping containers and/or equipment to attenuate the mechanical inputs of shock and vibration such that the loads and stresses will be lower than the design loads and stresses in operation.

5.1.2 Environmental Protection

The design of shipping containers and/or equipment shall be such that the V/STOLAND, during shipping, handling, and storage, including at NASA/ARC, shall have protection from expected environments of temperature, humidity, sand, dust, and salt spray, so as to be less severe than design envelope conditions.

5.1.3 Shipping Equipment Requirements

The contractor shall provide all shipping equipment which shall include shipping containers and dust covers.

5.2 Shipping

The contractor shall be responsible for shipping.

5.3 Delivery Site

Unless otherwise notified, the contractor shall deliver the V/STOLAND and its supporting equipment, with GFE, to NASA/ARC.

5.4 Storage

No special provisions except as given in Section 5.1.2.

6.0 NOTES

6.1 Definitions and Abbreviations

ALT - Altitude

ATE - Automatic or Automated Test Equipment

Auto - Autopilot

CFE - Contractor-Furnished Equipment

CRS - Course

CSS - Control Stick Steering

DDAS - GFE Digital Data Acquisition System

DME - Distance Measuring Equipment, Ultra High Frequency Navaid providing range information

EMI - Electromagnetic Interference

FD - Flight Director

FP - Flight Path, esp, Programmed Flight Path

FPA - Flight Path Angle

GFE - Government-Furnished Equipment

GSE - Ground Support Equipment

HDG - Heading

HSI - Horizontal Situation Indicator

IAS - Indicated Air Speed

INS - Inertial Navigation System

MFD - Multifunction Display

MODILS - Modular Instrument Landing System

MSP - Mode Select Panel

NASA/ARC - National Aeronautics and Space Administration, Ames Research Center

ADI - Attitude Director Indicator

Navaid - A Ground Radio Navigation Aid

SIU - Servo Interlock Unit

STOL - Short Takeoff and Landing (aircraft)

STOLAND - Airborne STOL terminal area navigation guidance and control system

TACAN - Tactical Area Navigation, ultra high frequency navaid providing bearing and range information

VOR - Very high frequency omni-directional range navaid providing bearing and range information

VOR/DME - Co-located VOR and DME navaids

VSD - Vertical Situation Display

V/STOL - Vertical/Short Takeoff and Landing

V/STOLAND - Airborne V/STOL terminal area navigation guidance and control system

VTOL - Vertical Takeoff and Landing